



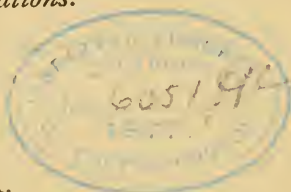


THE
FOUNDING OF METALS:
A PRACTICAL TREATISE ON
THE MELTING OF IRON
WITH A DESCRIPTION OF THE
FOUNDING OF ALLOYS;
ALSO,
OF ALL THE METALS AND MINERAL SUBSTANCES USED IN THE
ART OF FOUNDING.
COLLECTED FROM ORIGINAL SOURCES,

BY
EDWARD KIRK,
PRACTICAL FOUNDRYMAN AND CHEMIST.

Twenty-one Illustrations.

SHARON, PA.
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P R E F A C E.

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In ten years spent at molding, and in the foundry business, and four years in traveling through the United States, in introducing a chemical flux, for iron, I have seen the lack of regularity, and the bad effects of it, in the construction and management of foundry cupolas and furnaces, and the want of a guide or rule for their construction and management. At the earnest solicitation of many foundrymen, I have undertaken the publication of this small work, with a view of throwing some light upon the subject of melting iron, and the construction and management of cupolas and furnaces—a subject that always seems to be enshrouded in mystery.

All the theories that I have advanced in this work, are from notes taken from practical observation, while visiting different foundries, in the flux business, and from a chemical knowledge of the laws of combustion and heat, as well as of the laws of chemical affinity of one element for another. By giving a few explanations of causes and effect, I hope to establish some regularity in the melting of iron for foundry purposes.

I have also added a few recipes for the forming of alloys, and a general description of all the metals, minerals and gases used in the art of founding, as well as their application, all of which I have endeavored to place before the reader, clothed in popular language, so that all who can read may fully understand this interesting subject; for this reason, I have endeavored to avoid using any of the chemical and technical terms which are usually applied to this subject, as they often have a tendency to embarrass, rather than to enlighten, the reader.

THE AUTHOR.

CONTENTS.

	Page.		Page.
IRON	1	Dumping the cupola.....	67
Mixing and melting irons.....	14	Fire in the dumps.....	67
Hard iron.....	19	The dumps.....	68
Hard and soft iron.....	21	Pig-mold for over-iron.....	68
Soft iron.....	22	Combustion and heat.....	69
Burnt irons.....	23	The melting point.....	72
Shot-iron.....	24	Blast machines.....	76
Shrinkage of iron.....	26	The atmosphere.....	78
Coal.....	26	Fluxes and fluxing.....	79
Large coal.....	27	Limestone flux.....	80
Small coal.....	27	Oyster-shell flux.....	82
Coke.....	28	Fluor-spar flux.....	82
Coal and coke.....	29	Marble spalls flux.....	82
Charcoal.....	29	Patent fluxes.....	82
Cupolas.....	30	Charcoal flux.....	83
Construction of cupolas.....	31	Potato flux.....	83
The foundation.....	31	Clean iron and sound castings	83
Bottom plate.....	32	Polling iron.....	84
The iron bottom.....	33	Slag.....	84
Caisson or shell.....	33	Daubing for ladles.....	85
Cupola stack.....	34	Ladle rest.....	86
The scaffold.....	35	Percentage of fuel.....	86
Charging-door.....	35	Percentage of fuel and cast-	
Elevators.....	36	ings.....	96
Scales.....	37	Iron lost in melting.....	98
Lining.....	38	Melters.....	102
Fire-brick.....	39	The old melter.....	103
Tuyeres.....	40	Practical and scientific melt-	
Different shaped tuyeres.....	41	er.....	105
Capacity of copolas.....	44	Smart-Alic melter.....	107
High and low cupolas.....	44	Hot-blast cupolas.....	112
McKenzie cupola.....	48	Reverberatory furnaces.....	115
Return-flue cupola.....	49	Your neighbor and you.....	119
Straight cupolas.....	50	Scraps.....	122
Daubing the cupola.....	52	Malleable iron castings.....	123
Swivel cupola.....	56	THE FOUNDING OF ALLOYS...	131
The sand bottom.....	58	Metals and recipes for alloys	133
Front or breast.....	59	Alloys of iron.....	134
Two fronts or breasts.....	59	Platinum alloys.....	136
The spout.....	60	Gold alloys.....	136
Stopping bods.....	60	Silver alloys.....	137
Stopping or bod sticks.....	61	German silver alloys.....	138
Tapping bars.....	61	Bismuth alloys.....	139
Lighting the fire.....	62	Brass alloys.....	140
Charging with coal.....	63	Lead and copper alloys.....	141
Coal melters.....	64	Bronze alloys.....	141
Charging with coke.....	65	Bell-metal alloys.....	143
Coke melters.....	65	Type-metal.....	144
Pig-iron.....	66	Lead alloys.....	144
Pressure of blast.....	66	Spelter-solder alloys.....	145

	Page.		Page.
Hard-solder alloys	146	Anthracite coal	208
Soft-solder alloys.....	147	Brown coal	209
Babbitt anti-friction metal ...	147	Bituminous coal	210
Fluxes for alloys.....	148	Peat.....	214
Black flux.....	148	Clay.....	214
Nature and character of al-		Fire-clay	215
loys	149	Loam.....	216
Fusibility of alloys.....	151	Potter's clay.....	217
Brass furnaces.....	155	China clay	218
Crucibles	157	Soap-stone	219
Cupel.....	161	Asbestos	219
Blow-pipe	161	Sands.....	221
Brazier's hearth	163	Calcium.....	222
Burning together	165	Marble	224
Hard-soldering	168	Lithographic stone	224
Soft-soldering.....	171	Pummeystone	225
Table of metals	176	Silicon	225
Gold.....	178	Barium	225
Silver	185	Emery.....	226
Platinum, palladium, rhodi-		Garnets	226
um, iridium and osmium... 188		Amber	227
Platinum	188	Alum-slate	227
Palladium	189	Asphaltum	228
Rhodium	190	Sulphur	229
Iridium.....	190	Phosphorus	230
Osmium	190	Petroleum.....	231
Mercury.....	191	Boron	233
Copper.....	192	Iodine	233
Zinc.....	194	Chlorine.....	233
Tin	196	Bromine	234
Lead	198	Fluorine	234
Nickel	199	Salt	234
Antimony.....	200	Oxygen.....	235
Bismuth	201	Hydrogen	238
Arsenic	202	Nitrogen	239
Manganese	202	Carbon	242
Magnesium.....	203	Atmosphere	250
Aluminum	203	Water	253
Chromium.....	204	Combustion	260
Cobalt	204	Spontaneous combustion ...	264
Potassium.....	204	Bronzing.....	265
Sodium.....	205	Zincing.....	268
MINERALS AND GASES.....	207	Blackening iron castings.....	269
Fuels	207	Recipes for working steel ...	270
Mineral charcoal	208	Cement.....	271

I R O N .

The metal (iron) has been known from the very remotest ages of the world ; for we read in the scripture that Tubal-Cain was an instructor of every artificer in brass and iron. We read of iron in almost all of the ancient histories, except the history of the ancient Greeks. At the very earliest period of their history they do not seem to have known of the existence of iron,—far less the methods of working iron ; yet we read of iron in the histories of nations that were before the ancient Greeks ; and there is good reason to believe that, anterior to the earliest historical records of the Greeks, iron and the processes of working it were known in China and Hindostan. Yet, notwithstanding the fact that iron has been known from the very remotest ages, it does not seem to have been in general use in ancient times ; for in ancient history, as well as in the Bible, we read of very few purposes to which iron was applied ; for all the tools, cooking utensils, and arms and implements of war of the ancients seem to have been made of brass or bronze, and alloys of different metals. Whether the ancients did not know the value of iron, or whether they “went in” for the more showy alloys of metals is not known ; but for some reason the art of working iron was not cultivated by any of the ancient nations as was the art of making alloys of

brass, bronze, etc.; and all of the ancient nations seem to have understood to perfection the art of making and hardening brass and bronze,—an art that has been lost to modern nations. Yet, while we have lost the art of hardening bronze, we have discovered the art of hardening and tempering iron or steel,—an art that does not seem to have been known to the ancients; and the art of hardening and tempering iron or steel is of more importance to modern nations than the art of hardening bronze.

Although the metal (iron) has been produced from some of the several metalliferous sources from the earliest historical periods, yet new methods of working it, and new sources from which to obtain it, have multiplied so much in modern times as almost to rank in importance with the discovery of the existence of a new metal. Iron has been discovered in all parts of the world in large quantities, and is manufactured and worked by all civilized nations. The abundance of iron everywhere indicates how indispensable the Creator deemed it to the education and development of man. There is no California of iron; each nation has its own supply. Iron has come into such general use in modern times that the development of the iron resources of a country may readily indicate the advancement of a nation; for iron has become the symbol of civilization; its value in the arts can be measured only by the progress of the present age, in its adaptation to the useful arts; it has kept pace with the scientific discoveries and improvements, so that the uses of iron have become universal; it is worth more to the world than all the other metals combined. We could dispense with gold and silver, for they largely minister to luxury and refinement; but notwithstanding their nobility, they must yield the palm to iron, which represents solely the honest industry of labor. Iron is fitted alike for the massive iron cannon, for the great Atlantic cable, and for the watch

screws, so tiny that they can be seen only by the microscope, appearing to the naked eye like grains of black sand. For the last century almost all of the civilized nations of the world have seemed to vie with each other in the production of iron; and to this fact we owe all of our modern improvements in the manufacture and working of iron. In these new inventions and improvements the Americans have kept pace with the world; and why should we not keep pace with, or lead the world in the productions of iron? for our resources of iron ores and fuels are unlimited, and all that is necessary is to develop them.

Iron is sometimes found native, but it is a mere curiosity of no practical value whatever. Meteors, containing as high as ninety-three per cent. of iron, associated with nickel and other metals, have fallen to the earth from space. Iron is found in combination with almost all of the known elements, and in all parts of the world; it is found in our blood, in the blood of animals, and in the ashes of plants. Many minerals contain it in considerable quantities; and in fact there are very few minerals entirely free from it. But the principal source from which we obtain our supply of iron is from the oxides and carbonates of iron or iron ores. These ores are known by different names derived from their different chemical constituents, and from the different localities from which they are obtained; as the red hematite, the brown hematite, the black band, the spar ores, the magnetic ore, the iron pyrites, the Lake Superior ore, the bog ores, the Iron mountain ore, etc. All these ores contain more or less iron, locked up with oxygen in an apparently useless stone, and some of them are very rich in iron. The Iron mountain ore, which is found in the State of Missouri, is said to contain ninety per cent. of iron, and is the richest iron ore in the world. To obtain our supply of iron from these ores, we have only to separate the iron from its combi-

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nation with the non-metallic part of the ores. This is done by roasting and smelting the ores in blast-furnaces. These furnaces are of different sizes, and are called one-eighth, one-fourth, one-half, and full stacks; they are also divided into different grades, from certain obvious peculiarities in their construction and mode of working, and fuel used,—as the cold-blast, the hot-blast, the charcoal, the coke, or the anthracite furnaces. From these peculiarities of the furnaces the iron produced receives their different names,—as the cold-blast and hot-blast, charcoal irons, the coke iron, and the anthracite iron. The cold-blast furnace is a furnace that is blown with a cold blast, or cold air. This class of furnaces always use charcoal fuel, and they produce the best class of iron for machinery or any heavy work that requires great strength, such as rollers for rolling-mills, cannon, shafts and cranks for machinery, etc. This class of iron, although it runs soft in any heavy casting, will generally run hard in light castings; and it is never used in stove foundries, or in any foundry where light work is made. The cold-blast iron is the best iron for chilling, and is used in the manufacture of car wheels, crusher-jaws, and any castings that require a hard chilled surface. The hot-blast charcoal furnace is a furnace that uses charcoal as a fuel, and is blown by a hot blast. This furnace has an oven, filled with coils of pipe which are heated to redness. The cold blast is forced through these pipes, and then into the furnace; and when it enters the furnace it is heated to redness, and is termed hot-blast; and the products of this class of furnaces are termed hot-blast charcoal iron. This class of iron is the best iron that can be procured for general foundry purposes; for it may have both hardness and softness, and it has great strength, but it has not got the chilling properties of the cold-blast charcoal iron. This class of iron is extensively manufactured in the south-eastern part of Ohio, along

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the Ohio river, in what is known as the Hanging-rock iron region ; and the iron produced is termed Hanging-rock charcoal iron. The furnaces in this region are all small furnaces ; in fact, all charcoal furnaces are small, none of them being over one-eighth or one-fourth stacks. The Hanging-rock irons are principally used for foundry purposes ; and in the foundries through the southern parts of Ohio, Indiana and Kentucky there is very little iron used but the Hanging-rock irons. The coke furnaces are the furnaces that use coke as a fuel. All coke furnaces are hot-blast furnaces ; this class of furnaces is principally located through Western Pennsylvania, and along the Ohio river, and through the Western States. The products of these furnaces are termed coke iron. This iron is sometimes used in foundries ; but the principal part of it is used in rolling-mills in making wrought irons. The coke furnaces are the largest furnaces in this country. The Luey furnace and the Isabell furnace, at Pittsburg, are twenty feet in diameter on the inside ; these furnaces have each produced over a hundred tons of pig-iron every twenty-four hours. There is a very large coke furnace at Irlington, on the Ohio river ; that was put in blast about two years ago ; this furnace is said to be the largest and best furnace in the world ; it was built by the iron men of the Hanging-rock region. A man was sent all over this country and Europe to get all the modern improvements for it before its construction, and it has all the modern improvements combined, and is said to be perfect.

The anthracite furnaces are the furnaces that use anthracite coal as a fuel. All of this class of furnaces are hot-blast furnaces, and the product is termed an anthracite iron. This class of iron is extensively used in foundries, and is a good iron for stove plate and all kinds of light castings. The anthracite furnaces are principally located through the eastern part of Penn-

sylvania, and in New York, New Jersey and Maryland, and are generally small furnaces.

A great many improvements have been made in blast-furnaces in the last few years, and they have been brought to a state of comparative perfection; but most all of these improvements have been made with a view of increasing the yield of iron from the ores and of making a cheaper iron. Most all of these improvements have had a tendency to deteriorate the quality of the iron rather than improve it, so that the foundrymen have a worse iron to work, to-day, than they had some years ago.

To smelt iron from its ores, in the blast-furnace, the ores, fuel and limestone are put into the furnace together in layers or charges; the fuel is to create heat and smelt the iron from the ores; the ores are to produce the iron, and the limestone is to act as a flux and impart igneous fluidity to the non-metallic residue of the ores and fuel, and carry it out of the furnace in the shape of slag or cinder. Practice has demonstrated the fact that, by mixing two or more ores in the furnace, the impurities in one ore may be made to impart igneous fluidity to the non-metallic residue of the other, and furnacemen have adopted the theory of using two or more ores, each having different chemical constituents, and in so doing, less limestone is required as a flux in the furnace. As the iron is smelted from its ores, it drops into the hearth or bottom of the furnace, and is drawn off in a channel cut in the sand in the floor of the casting-house, and from this main channel it is run into molds or pigs. As the iron chills in the mold it is called pig-iron or cast-iron, and the iron remaining in the large channel is called the sow-pig—hence the term pig-iron.

There are a great many different varieties of iron; the principal ones are cast-iron, wrought-iron and steel. The difference between these irons is caused by the different proportions of carbon and other impurities

which they contain. Cast-iron or pig-iron is the form of the iron as it comes from the blast-furnace; it is brittle and cannot be welded, and it is neither malleable nor ductile. This iron expands at the moment of solidification, so as to copy exactly every line of the mold into which it is poured, and it contracts on cooling. These qualities fit it for casting into sand or other molds; and these castings may be made so soft as to be easily filed or turned, or they may be made so hard, by chilling in an iron mold, that no tool will cut them. Cast-iron contains from two to five or six per cent. of carbon, and as the carbon increases or diminishes, the iron becomes harder or softer, and is termed a No. 1, 2 or 3 iron. That which contains the most carbon is the softest iron, but it is not always the strongest iron. As the carbon decreases, the cast-iron grows harder, and after it gets past a certain point it grows weaker. Cast-iron is often combined with other substances as well as carbon; it has a great affinity for sulphur, phosphorus, silica, and other impurities; it is also often alloyed with manganese, forming speigel-eisen iron; with chromium, forming chromic iron; with copper, forming red-short iron; with lead and other metals, forming cold-short iron. These alloys often cause cast-iron to be hard as well as brittle.

Wrought-iron, as it is termed, is cast-iron that has been deprived of its carbon and some of its other impurities. This is done by burning the carbon from the cast-iron in a current of highly-heated air in a reverberatory furnace. The iron is melted in the furnace, and is stirred and boiled up and exposed to the heated air by means of long puddling-bars, as they are termed. After it has been stirred and boiled until it ceases to be fluid, it is then worked into balls and is taken out of the furnace while white-hot, and crushed in the squeezers or under the trip-hammer, to force out the slag and convert it into blooms. It is then run through

grooved rolls to bring the particles of iron nearer each other and give it a fibrous structure; and by means of rolling, it is converted into bar-iron, sheet-iron, etc. It is then malleable and ductile, and can be forged and welded; yet in bailling and puddling cast-iron to convert it into wrought-iron, it is impossible to separate or burn away all of the impurities, or other metals that may be alloyed with the cast-iron, so that, in wrought-iron as in cast-iron, we have three divisions of iron—as red-short, cold-short, and neutral-iron. The red-short iron is an iron that is brittle when red-hot, and strong when cold. This class of iron is not used for bar-iron or any other iron that requires to be heated or forged, but it is principally used for sheet-iron, cut-nails, etc. Cold-short iron is an iron that is brittle when cold, but is very tough when hot. This quality fits it for forging better than any other iron, but as it has very little strength when cold, it is seldom used alone except for cheap grades of bar-iron. Neutral-iron is an iron that is neither brittle when cold or hot, but is between the extreme red-short and cold-short irons, and it is made by mixing the red-short and cold-short irons together. The neutral-iron is the best iron for all kinds of bar-iron, and all our best bar is made from it.

Steel is an iron that contains less carbon than cast-iron, and more than wrought-iron. It is made by converting cast-iron into wrought-iron, and then adding a small percentage of carbon by heating wrought-iron bars in a box or oven surrounded by charcoal. These bars of carbonized iron are then melted in crucibles and cast into ingots, and are called cast-steel ingots; hence the term cast-steel. It is said that the inventor of cast-steel was a watchmaker named Huntsman, who lived at Attercliffe, near Sheffield, in England, in the year 1760. He became dissatisfied with the watch-springs in use, and set himself to the task of making them homogeneous;—if he could melt a piece of steel and

cast it into an ingot, its composition would be the same throughout. He succeeded; his steel became famous, and Huntsman's ingots were in universal demand. He did not call them cast-steel, for that was his secret. The process was wrapped in mystery by every means; the most faithful men were hired; the work was divided; high wages were paid, and stringent oaths taken. One midwinter night, as the tall chimneys of the Attercliffe steel works belched forth their smoke, a belated traveler knocked at the gate; it was bitter cold; the snow was falling fast and the wind howled across the moor. The stranger, apparently a common farm-laborer seeking shelter from the storm, awakened no suspicion; the foreman of the works scanning him closely, at last let him in. He feigned to be worn out with cold and fatigue, and sank upon the floor and was soon seemingly fast asleep. That, however, was far from his intention; he cautiously opened his eyes and caught a glimpse of the mysterious process; he saw workmen clothed in rags, and wet to protect them from the tremendous heat, draw the glowing crucibles out of the furnaces and pour their contents into molds. Huntsman's steel works had nothing more to disclose, and the secret of cast-steel was stolen. The value of steel depends largely upon its temper; too much carbon causes steel to be poor and too much like cast-iron; too little carbon causes steel to be like poor wrought-iron; hence the importance of having just the proper amount of carbon. Steel is tempered by heating and cooling it suddenly by plunging it into cold water, oil, damp sand or anything that will draw the heat from it suddenly. The workmen decide the quality of the temper by the color of the oxide that forms on the surface of the various kinds of work requiring different tempers. Cold chisels and machinists' tools require a straw-blue tint; razors require a straw-yellow; springs and swords, a bright blue, and saws a dark blue.

In the last few years several new processes of making steel, direct from the pig-iron, have been introduced, and are now in operation. The principal process in use at the present time is the Bessemer process. This process of making steel consists in melting several tons of pig-iron in a cupola, and pouring it into a large converter, hung on two pivots, so as to be easily tilted. Air is driven into the converter through the bottom, and is forced up through the molten metal, causing it to bubble and boil, and producing an intense combustion. The roar of the blast, the hot, white flakes of slag, ever and anon whirled upward, the long flame streaming out at the top of the converter, variegated by tints of different metals, and full of sparks of scintillating iron, all show the play of tremendous chemical force. The operation takes about twenty minutes, when the iron is purified of its carbon; and *silex*, enough *speigel-eisen* cast-iron—an iron rich in carbon and manganese—is then added to convert it into steel. Then it is poured out and cast into ingots. It is then hammered or rolled into any desired shape. The Bessemer steel is principally used for railroad steel rails.

Pure iron is far more rare and more difficult to obtain than absolutely pure gold; it is only met with in chemical laboratories, and very seldom there. Wrought-iron, however, is considered as pure iron; but it is only commercially pure, as it always contains more or less impurities.

Cast-iron is iron combined with some four or five per cent. of impurities. With a view of getting rid of the four or five per cent. of impurities contained in cast-iron, and giving us a purer wrought-iron, the puddling process was invented by Richard Corts. The steam jet and atmospheric-air process was invented by Mr. Plant. The process of applying either air or steam from below was invented by Mr. Martin. The process of refining iron by a process of granulation was invented by Mr. Clay; and several other processes of refining

iron have been invented. The object of all these inventors has been to rob the cast-iron of its four or five per cent. of carbon, or impurities. That this four or five per cent. of carbon in cast-iron is not barren of all good results, will be seen by a consideration of the products made of cast-iron and wrought-iron respectively. Cast-iron, by losing its carbon, loses its fluidity, and wrought-iron is almost infusible; yet, by virtue of its malleability and power of adhesion under the operation of welding, wrought-iron may be converted into a multitude of useful forms. But if we look over the comparative numbers and variety of the products of cast-iron and wrought-iron respectively, and reflect on the advantages of the fluidity imparted to cast-iron by its impurities, we will rise from the survey with the conviction that the existence of these impurities in cast-iron is not without its advantages; for to these impurities we owe the enormous development which the products of cast-iron have attained. If cast-iron was deprived of its carbon the genus of smelting and casting operations would all be gone; and, instead of the facility wherewith the genus of our smelting and casting operations enable us to turn out enormous quantities of iron cast into the form required, every piece of manufactured iron would necessarily have to be manufactured by the laborious operation of forging, hammering and welding; the price of iron for many purposes would be enhanced in value, and, for numerous purposes to which it is now applied, it could not be used at all. Imagine the pieces of cast-iron that constitute the anchors of the Brooklyn bridge, and contemplate the price of wrought-iron pieces of the same circumference, having the same weight, form and dimensions, hammered and welded into shape, instead of cast; it would have been utterly impossible to have made them, notwithstanding the aid of our ponderous steam hammers. The ease with which a blacksmith heats, and

welds, and fashions into shape upon his anvil the glowing wrought-iron, conveys but a feeble indication of the difficulties which beset the working of wrought-iron in large masses. It is difficult to establish the extreme limits or size of which a piece of wrought-iron admits of being forged; but there is a limit reached by the failure of power to heat the mass of metal to the welding heat, and by the tendency of wrought-iron, in large masses, to crystallize and lose its fibrous structure when subjected to a long continuous heat. As has been intimated, almost all of the new inventions and improvements in the manufacture of iron have been introduced with a view of making wrought-iron or steel; and the inventors of these processes have attempted to make almost every product of iron out of wrought-iron or steel; and in some of these undertakings they have succeeded, and in others they have failed. In fact, they have failed or accomplished nothing in all cases where they have attempted to apply wrought-iron in large masses in place of cast-iron. It is true that wrought-iron shafts, cranks, plates for gun-boats, etc., have been manufactured, and have given better results than the cast-iron of to-day would have done, but they are no better than the cold-blast charcoal iron of the past, or the cold-blast charcoal iron of to-day. Heavy cannon have been made of wrought-iron, but in almost every case they have proved failures. Steel cannon have been made, and several very large ones were on exhibition at the Centennial Exhibition at Philadelphia. These cannon are said to be superior to either the wrought-iron or cast-iron guns; but they have not been brought into general use yet, and little can be told about them by the few that have been made as experiments; but there is no doubt but what the steel gun can be made superior to the iron gun made from hot-blast iron; for we can add enough carbon to steel to make it a refined cast-iron, and still be called steel.

The improvements in the manufacture of wrought-iron and steel have become matters of actual necessity ; for all the improvements in the construction of blast-furnaces and the productions of cast-iron have had a tendency to make a poorer iron. When we had the charcoal iron it was a superior iron, and it answered many purposes to which wrought-iron is now applied ; but when the hot blast was introduced, and the use of anthracite and bituminous coal or coke was adopted as a fuel, cast-iron no longer had the purity of the charcoal iron, but was deteriorated by the impurities contained in the fuel. Analysis of coal or coke-smelted iron demonstrated the existence of both sulphur and phosphorus incorporated with it ; the analysis also demonstrated that these impurities were in direct proportion to their proportions contained in the fuel, and to overcome these impurities the manufacturers of wrought-iron have adopted new ways of working and manufacturing their irons. But the foundrymen have jogged along in the good old way, and took the pig-iron as they got it, and turned out castings accordingly ; and while the wrought-iron manufacturers have kept up the standard or improved the quality of their iron, the foundrymen have made a weaker casting, so that a great many things are now made of wrought-iron that were made of cast-iron in times past. When we look over the country and survey the respective products of cast and wrought-iron, and see the hundreds of tons of castings that are turned out of our foundries daily, the enormous amount of stoves that are manufactured, and contemplate the endless amount of trouble that the foundrymen have in getting an iron that will make a first-class casting, the question naturally arises : Why does the inventor not start at the blast furnace and improve the iron in the pig, instead of at the rolling-mill ? I see no reason why he should not, unless it is that the wrought-iron manufacturer is ambitious to make a good iron, and

offers some inducements to inventors, while the foundrymen are only ambitious to make a cheap casting and undersell their neighbors, and offer no inducements to inventors.

MIXING AND MELTING IRONS.

The foundryman cares little or nothing for a chemical analysis of iron, which merely shows the exact amount of different impurities it may contain; but the question that the foundryman asks, is: What irons can I work, and how can I mix them so as to produce a good, clean, strong and *cheap* casting? This is a question that is almost impossible to answer, as it is impossible to give a complete vocabulary of all the impurities which iron may contain, with their effect upon the iron in different proportions, as these proportions may be varied in remelting and produce different results; and even if it were possible, the foundryman does not wish to go to the trouble of making a chemical analysis of every lot of iron he gets in, to ascertain its impurities and to keep track of how it may be mixed with some other lot of iron. Little can be told by looking at an iron in the pig, whether it will run hard or soft when remelted and run into castings, or whether it will mix with another brand of iron. The foundryman, or an expert, may by actual tests become acquainted with all the iron and ores used in a certain locality, and, by looking at the iron in the pig, tell very nearly what it will do when run into castings; but the best expert in the country can tell little or nothing about an iron that he has not been accustomed to working, and he will often be deceived in those he has been accustomed to, by merely looking at the iron in the pig. True, he may make a good guess, and he may tell whether an iron will run extremely hard

or soft, but that is all that can be told by the looks of an iron in the pig.

It is impossible to qualify the various kinds of pig-iron brought into the market by local terms and marks. It would not, after all, be of any use, because the furnacemen may change their ores or their mode of charging the stock, and change the product of the furnace from a No. 1 iron to No. 2, or even No. 3 iron, which makes a great difference in its application in foundries; or a furnace may change the quality of its iron without any change of the ores, and without any apparent cause for the change in the quality of iron. When operating at Lewisburg, Pa., last spring, I found a lot of pig-iron that was made at the Dry Valley Furnace, Pa. This iron, when remelted and run into a cylinder head that was nearly two inches thick, was so hard that it could not be drilled, yet the iron in the pig was of a dark-gray color with a large open crystal, and to all appearance was a No. 1 soft foundry iron. This iron was made from the same ores that the furnace had been using for years. In making a No. 1 foundry iron, no change had been made in the mode of stocking the furnace, and there was no apparent cause for the change in the quality of iron. This furnace, after it had been in blast for a short time, got to working so badly that it became necessary to blow it out. It was then found that when putting the furnace in blast, it had scaffold on one side, which was the cause of the hard iron. If a blast furnace, with the fire only on one side of it, will change the nature of iron as this furnace did, then a cupola, with the fire or the blast all on one side of it, will change the nature of iron when remelted. I have seen two cupolas melting the same iron, and one produced good soft, strong castings, and the other produced hard or brittle castings. I have always found that the cupola that produced the hard or brittle castings, either had the blast all on one side of it, or that the fire was not

burnt up evenly, and that the stock was not charged regularly.

Cast-irons admit of a division into three classes and seven grades. The three classes are : the red-short, the cold-short, and the neutral-iron. The seven grades are the seven qualities or seven numbers of iron, as No. 1, No. 2, or No. 3. Red-short iron is an iron that has no strength when red-hot, and has a great deal of shrinkage. An extreme red short iron will shrink as high as one-fourth of an inch to the foot. Red-short iron, when used for casting pipe on their end, will cause the body of the pipe to shrink down and leave the bowl of the pipe before the iron has thoroughly set ; and when used in other castings, such as grate-bars, it will tear off and form cracks in the corners while hot : it will cause chill-cracks on the tread of a car wheel, but they are not deep and do not injure the wheel. Red short-iron may be either hard or soft, and is liable to go to extremes either way. It never breaks from shrinkage when cold.

Cold-short iron is an iron that has no strength when cold, and has very little shrinkage ; it will resist very little strain, and if the patterns are the least bit out of proportion the casting will break from shrinkage after it is cold ; it will cause stove-plates to crack under the spews. Cold-short iron may be either hard or soft, and is liable to go to extremes either way ; but it never breaks from shrinkage when hot.

Neutral-iron is an iron between the extreme red-short and cold-short irons ; it is made by mixing the red and cold-short irons together. A neutral-iron is the best iron for foundry purposes, and furnacemen who make a business of manufacturing foundry iron make it a point to mix their ores so as to make as near a neutral-iron as possible. Yet in some localities one ore may be cheaper than another, and it may be used to excess, which may make an iron inclined to be either

red-short or cold-short, yet not extreme either way. The foundryman that is using three different brands of iron may find at times that he has two brands of iron inclined to be cold-short, and one brand inclined to be red-short. If these three irons are mixed in equal proportions they will make a casting inclined to be extreme cold-short. Yet one-fourth of the two brands and one-half of the third brand, mixed together, may make a neutral-iron and a good strong casting; or by leaving out one of the brands, and using one-half of each of the other two brands, the same results may be attained. The only practical way to ascertain whether an iron is either red-short or cold-short, is by actual tests in mixing and melting the iron in different proportions, and testing the strength and shrinkage. A neutral-iron should not shrink more than one-eighth of an inch to the foot. Stove-foundrymen should be careful to use as near a neutral-iron as possible, and to change their brands of iron as little as possible; as the changes of iron often change the shrinkage, and will make trouble in mounting the stoves when much odd plate is kept on hand. When new brands of iron are introduced, test bars should be made to ascertain the shrinkage, and the different brands of iron should be varied so as to keep the shrinkage as near alike as possible.

The same theory may be followed in mixing irons to make a soft iron, thus: three brands of iron, mixed in equal proportions, may make a hard iron, while any two of the same brands, mixed in equal proportions, may make a soft iron. Tests were made last fall at Perry & Co.'s stove works in melting the three brands of iron, viz., Crane, Hudson and Jagger. These three irons were melted at the rate of fifteen per cent. of Hudson to eighty-five per cent. of Crane and Jagger together. This mixture made a hard iron. One-third of each brand was then melted together, and made a hard iron. One-half Hudson to one-fourth Crane and one-fourth

Jagger were then tried, and the result was a hard iron. The Hudson and Crane were then tried together—one-half each—and made a good soft iron. The Hudson and Jagger were then tried together—one-half each—and made a good soft iron. The Crane and Jagger were then tried together—one-half each—and made a hard iron. Thus the Hudson would neutralize either the Crane or Jagger separately, but would not neutralize them when put together in any proportion.

Iron will combine with almost all of the sixty-four known elements; and these elements, combined with irons in different proportions, will destroy the affinity of one brand of iron for another; and foundrymen, in mixing their iron, will generally use equal proportions of all the brands of iron that they are using; thus one-half, one-third or one-fourth of each brand. If the castings come hard, they will reduce the No. 2 and increase the No. 1 iron; and I have often seen foundries that were using all No. 1 iron, that were still troubled with hard iron. This was because they were using irons that had no affinity for each other, and would not unite so as to form a homogeneous iron; and throwing out the No. 2 iron gives only a temporary relief by the excess of carbon in the No. 1 iron, overcoming the non-affinity of the irons; and if the No. 1 iron happened to be a little poorer, one day than another, the iron was hard and uneven. I have often seen foundrymen that had one brand of iron in their yard that they had had on hand for years, and could not use it; and perhaps the next foundryman that I would meet would be using that same brand of iron, and could not get along without it. This was because the one foundryman was using other iron as a mix that had an affinity for that particular brand of iron; or the two foundrymen might be using the same iron as a mix, and mixing them in different proportions, which produced different results. Two poor irons can often be

mixed together so as to make a good iron; as is the case in mixing the extreme red-short and cold-short irons which forms a neutral iron that is superior to either the red-short or cold-short irons for foundry purposes. In mixing irons, I should recommend mixing them, and varying the mixture by the local brands or marks, and not by the numbers of the iron. To make a good iron, at least one-third of No. 2 iron should be used; and if all No. 2 irons can be used and make a soft iron, they will make a superior casting to all No. 1 iron. In melting iron I should recommend melting it hot, and as fast as possible. A quantity of molten iron should be kept in the cupola, or in a large ladle, so as to give the different brands of iron a chance to mix. In most all the foundries at Wheeling, West Va., the cupolas are never stopped in from the time the blast is put on until the bottom is dropped. A large ladle is set on trestles in front of the cupola, in such a manner that the iron can run into it from the cupola, and be poured out into the smaller ladles at the same time. The iron is all run out of the cupola as fast as it is melted, and is mixed in the large ladle. I think this is a good way of mixing irons. See ALLOYS.

H A R D I R O N .

Most every foundryman is troubled more or less with hard iron, especially if they are manufacturing light castings. Hard iron is sometimes caused by using a poor quality of iron in the first place, or poor fuel, or by using too much shot-iron, or rusty scrap. The dampness in the sand bottom will cause the first iron to be hard. Iron boiling in a green ladle will be hard if run into light plates. Sand worked too wet, or rammed too hard, or spunged too much, will cause hard iron. Thus.

hard iron may be traced to a great many causes ; but the principal cause of hard iron, when good stock is used, is the unscientific way in which cupolas are constructed and charged. It is a well-known fact that Nos. 1, 2 and 3 irons are made in a blast-furnace from the same stock,—the different grades of iron being caused by the different temperature at which the ores are melted. If a large cupola is constructed with only one tuyere the blast cannot be forced into it so as to give an even temperature : or if the tuyeres are not placed at equal distances apart, or if they are so placed that one or two of them will take nearly all the blast, and the balance of the tuyeres get little or none at all (as is often the case), the result will be an uneven temperature in the cupola, and an iron hard and soft in spots. Cupolas are often charged with large coal in the bed, which forms large crevices between the lumps, through which the cold blast penetrates to the center of the cupola, and strikes the hot iron as it drops through the coal and chills and hardens it. The bed is often put in without any regard to whether it is level or not on top when the iron is charged. The first charge of iron is thrown in, and the second charge of coal in the same hap-hazard way. If the cupola is large, and many gates or sprews are used, they will probably all be found in a pile on the side of the cupola, where it is handy to throw them from where the man stands that shovels them in. The iron will invariably be higher just under the charging door than anywhere else. The coal or coke is thrown in, and, if small, will roll to the lowest place ; thus having a large body of fuel in one place and little or none in another place. This uneven charging makes an uneven temperature, and a hard and soft iron ; or the iron may be charged even, and each charge leveled up, and the coal put in on it in large lumps (as is often the case), so that the small amount used will not more than half cover the iron, and will not separate the

charges of iron properly. The result is the same as when the charges of iron are not leveled up—an uneven temperature, and hard and uneven iron. I have seen two stove-plate foundries, in the same city, not more than two squares apart, melting the same brands of iron mixed in the same proportions, each using the same quality and same percentage of coal; and one foundry always had good soft iron, and the other one was always troubled with the iron running hard in spots. On examining the cupola, where the hard iron was made, I found it to be a round cupola four feet six inches in diameter, with a stack five feet or more in diameter. This cupola had five tuyeres; one was directly in front, and in line with the supply pipe; the others were scattered around at irregular distances apart. The tuyere in front of the supply pipe was admitting almost as much blast into the cupola as all the other four tuyeres put together, especially towards the last of the heat, when the tuyeres became clogged up. The iron was put into the cupola in charges of 4,400 lbs., and the coal in charges of 350 lbs. The coal was put in in large lumps, and was not near enough to cover the iron, or separate the charges of iron properly. The stack of this cupola was too large to concentrate and equalize the heat, the tuyeres were not arranged so as to give an equal amount of blast to all parts of the stock, and the coal was not charged even enough to give an even heat, and the iron was not melted at an even temperature, which was the cause of the hard spots.

HARD AND SOFT IRON.

When hard and soft iron are melted in the same cupola, as is often the case in jobbing and small foundries, the hard iron should be melted first one heat, and

soft iron first the next heat, as part of the last iron will always stick in the lining; and if the hard iron is melted last, and the soft iron first, the next heat the first few ladles will be more or less hard, from the small particles of hard iron remaining in the cupola from the former heat.

Melting hard and soft iron in the same heat is a bad practice.

S O F T I R O N .

To melt iron soft and even, with an even shrinkage, it must be melted at an even temperature, and the nearer we can come to a natural draft the better for the iron. The tuyeres should be put in at equal distances apart, and so arranged as to admit an equal amount of blast at each tuyere. The tuyeres should be of a size to correspond with the blast pipe from the fan or blower, and the fan or blower should be run to suit the cupola. A too sharp and cutting blast is injurious to the iron, and slow melting is equally injurious, so that we must have a mild blast and volume enough of blast to do fast melting. The stack of the cupola should be small, and high enough to give the cupola a good, even draft; the bed should be evenly lit up, but not burnt too much before the iron is charged. Small coal or coke should be used all through the heat, and each bed of coal or coke should be properly leveled up before the iron is charged on it; so should each charge of iron be leveled up before the coal or coke is charged on it. The iron should be charged into the cupola from one to three hours before the blast is put on (according to the draft of the cupola), so as to have it heat up gradually and anneal. The iron should be put into the cupola in large charges, so as to give a good bed of coal or coke between the charges and separate them properly without using too

much fuel. When different brands of iron are used, the cupola should never be tapped close, but a few hundred of molten iron allowed to remain in the bottom of the cupola so as to give the iron a chance to mix.

BURNT IRONS.

When in the malleable-iron business, I often tried to melt the annealing boxes in a cupola, with coke, after they had been burnt out, but I could never produce more than fifty per cent. of iron, and the iron produced was so mixed with slag that it could not be used for castings without remelting. The iron produced was always white and hard. I made a test at the American Stove and Hollow-ware Company's foundry in Philadelphia, Pa., in July, 1874, in remelting annealing pots that had been used for annealing hollow-ware. These pots were about two inches thick; they were charged in the cupola in the ordinary way, Lehigh Valley coal being used as fuel. The result of this test was a product of about seventy per cent. of iron, which was so mixed with slag that it could not be run into castings; the iron was also white and hard. The larger percentage of iron produced when remelting the hollow-ware annealing pots than was produced when remelting the malleable-iron annealing boxes, was caused by the hollow-ware pots being heavier and not so badly burnt, and not by the different fuels used in remelting. The best way that I have found for melting burnt iron in a cupola is to put it in the cupola with the regular charges of good iron, a little at a time; it will then act as a flux, and is better than limestone, especially if the iron is badly burnt; but care should be taken to not use too much of it at a time, as it will harden the good iron if used in too large quantities.

SHOT - IRON .

Every foundry has more or less shot-iron, or fine scrap, from the rattle barrels and gangways. This class of iron, although made from the best of pig-iron, will run hard when remelted, and in some cases will not mix with other iron (especially if the shot is rusted), but will cause hard specks in machinery or heavy castings, and will often sandwich in stove plate or light castings, forming a plate hard in the centre and soft on each side. Foundrymen who run exclusively on first class work have considerable trouble in getting rid of this class of iron, and it is often thrown out in the dump rather than remelt it. I made a test in remelting shot iron at the Baldwin Locomotive Works in Philadelphia, in June, 1874. In this test the shot-iron was put up in wooden boxes, each box holding from seventy to eighty pounds; one ton was then charged in a cupola, in the ordinary way, without any pig-iron or other heavy iron; the result of this test was a white, hard iron when run into pigs, and a wastage of twenty-five per cent. I do not think that anything was gained by putting the iron in the wooden boxes, for the boxes were all burnt up before the iron even became hot.

I also made some tests in melting shot-iron at a stove works in Louisville, Ky., in May, 1875. In these tests the shot-iron was charged on the first bed of coke, with a view of melting it first and using the iron for warming the ladles, and then pouring it into the pig-bed or some heavy work. This way of melting the shot-iron was a success so far as getting rid of the shot and using the iron was concerned; but it was found that the cinder and dirt, mixed with the shot-iron, formed a coating of slag and dirt over the bed and prevented the cupola from melting; and a much larger percentage of fuel had to be used when the shot-iron was charged on

the bed. Tests were made at the foundry of Perry & Co., at Albany, N. Y., in melting a lot of shot-iron that had got mixed with fine coal, and in order to separate the iron from the coal, they thought they would burn the coal under their boiler and melt the shot-iron, and have it run through the grate bars into the ash pit, and collect it in pigs. With this view, a thin layer of fine coal and shot-iron was spread over the fire, and the furnace closed up and the blast put on. Mica had been put into the furnace doors, so that the effect of the heat upon the iron could be seen. The result of this test was, that when the iron came near the melting point the small shot threw off beautiful fiery stars of all colors and shapes, making a beautiful fire-works; and in these fiery stars all the iron was converted into the black oxide of iron, so that not a particle of iron could be found either on the grate bars or in the ash-pit at the conclusion of the test. I have observed, in making tests to ascertain the percentage of iron lost in melting, that the percentage of loss was always greater when the shot-iron was charged through the heat; and from different tests that I have made in melting shot-iron, I have concluded that it should not be charged on the bed or in the first of the heat, because more fuel will be required to make hot iron. It should not be charged in small quantities through the heat, for it is too much exposed to the gases of the cupola, and the oxygen of the blast converts it into the black oxide of iron, and it is lost. I find that the best results are produced when the shot-iron is charged in a large body, as it was at the Baldwin Locomotive Works; it then lays compactly together and the heat melts it before the oxygen of the blast can convert it into an oxide. I think the best way for melting shot-iron in a cupola is to charge it after all the other iron has been charged into the cupola; it then forms a cover over the iron and prevents the escape of the heat, and the loss by the wastage of iron may be

made up by the saving of fuel. It also improves the quality of the shot iron to melt it at the last of the heat when the cupola is hot. Shot-iron, if melted and run into pigs, will mix with other iron when remelted.

Shot-iron has been melted in iron boxes or pots with about the same results as in the wooden boxes.

SHRINKAGE OF IRON.

Irons will vary in shrinkage. Some irons will not shrink any, and others will shrink as high as a quarter of an inch to the foot. The average shrinkage, and the shrinkage always counted on in making patterns, is one-eighth of an inch to the foot.

COAL.

Lehigh Valley coal is considered the best coal for melting iron because it is harder than some of the other coals, and is more free from sulphur; but coal from the Lackawanna Valley, and Schuylkill Valley, or Pottsville region, is also extensively used in the melting of iron in foundries. In selecting coal for the cupola, care should be taken to get as hard and solid a coal as possible, and a coal that will not slack down when the heat strikes it. Most any of the anthracite coals can be used for melting iron in cupolas. When the coal is soft or poor, a much larger percentage of coal must be used, and the charges of coal must be increased in weight towards the last of the heat, as will be seen by reference to melting done at the car works at Berwick, Pa., where the coal used was soft coal, from the Wilksbarre region.

L A R G E C O A L .

The majority of foundrymen and melters believe that it is impossible to melt iron without large coal, and they will always select the largest lumps they can get and put them in for the bed; some plate or other light scrap is then charged on the coal, to prevent it from being broken up by throwing in the pig or other heavy iron. This, they claim, makes a bed that will last longer and do better melting than a bed of small coal. The first charge of iron is put in on the bed, and then the second charge of two or three hundred of coal is put in in large lumps, as before, and probably will not more than half cover the bed of iron. The next charge of iron is then put in, and the next charge of coal in the same way, and so on. The blast is put on, and the cold wind finds the large openings between the large lumps of coal (which will naturally be formed by throwing large lumps of coal in a pile), and will penetrate to the center of the cupola before it becomes hot; the iron is melted on top of the bed, and runs down through the large lumps of coal like water through a stone pile, and passes through the cold blast which is constantly coming in, and the iron is decarbonized, chilled and hardened. The "old-fogy" idea of using large coal for melting iron in cupolas is the cause of more hard and uneven iron than anything else.

S M A L L C O A L .

I have made some thorough tests in melting iron with different sized coal, and I have found that good melting can be done with any size if the coal is good. The egg size coal is a good size for small cupolas; and what is known as grate or steamboat coal is the best size for

large cupolas; and I should recommend it for the melting of iron in cupolas in preference to large coal for the following reasons: It will pack closer in the bed than large coal, and will last equally as long; the blast will be heated before it can penetrate any distance into the cupola; the iron, being melted on top of the bed, will be slowly filtered down through the bed, and will be purified and superheated before it reaches the sand bottom. The second charge, of two or three hundred of coal, can be spread over the charge of iron so as to completely cover it and separate the charges of iron,—thus making the iron melt at a more even temperature, which will make a softer and a more even iron. A smaller percentage of coal will be necessary than when large coal is used. Foundrymen should be careful when using small coal to get the best hard coal, as it produces the best results.

C O K E .

Coke is extensively used for melting iron in cupolas for foundry purposes through the Western and South-western States. Connelsville and Pittsburg coke is considered the best coke for foundry purposes. The Steubenville and other Ohio cokes are sometimes used for melting iron; but they contain so much sulphur that they cannot be used in melting iron for stove-plate or other light work, as the coke does not have body enough to give life to the iron, and the sulphur hardens it and makes it brittle. Gas-house coke is sometimes used for melting iron, and does very well when it is made out of Connelsville or Pittsburg coal; but it has not as much body as the Connelsville or Pittsburg coke, and more of it has to be used to give life to the iron. Gas-house coke, made from cannel

coal, cannot be used for melting iron in cupolas. Poor coke will improve if left laying out in the weather for a long time. Wet coke seems to make hotter iron than dry coke.

COAL AND COKE,

When coke is used for melting iron in a cupola, a much larger heat can be melted than could be melted in the same sized cupola with coal. Coke will melt iron faster than coal. Coal or coke will make iron equally hot and fluid. Coal will make more slag than coke, and the cupola will be harder to pick out when coal is used than when coke is used. Iron will take up sulphur more readily from coke, and will be infused more from sulphur in coke than from sulphur in coal. Poor coke is worse than poor coal for melting iron. More blast is required for melting iron with coal than with coke. I have seen a great deal of melting done with both coal and coke, and I consider that equally as good melting can be done with the one as the other.

CHARCOAL.

Charcoal will make iron softer, stronger, and more fluid than coal or coke. Yet, notwithstanding these facts, charcoal has, on account of being expensive, been generally abandoned as a fuel in the melting of iron in cupolas for foundry purposes, although it is still used in some parts of the country where wood is plenty, and coal or coke is expensive, or when the quality of the castings is more of an object than the expense of making them. When charcoal is used for melting iron in a cupola, the cupola should not be as high as the coal or

coke cupola. Three or four feet is the best height for a charcoal cupola. The iron should be charged in small charges, and a mild blast used. Only small quantities of iron can be melted at a time with charcoal fuel.

C U P O L A S .

The cupola furnace has almost entirely taken the place of the reverberatory furnace for melting iron in foundries, because they have the advantage over the reverberating furnace of melting either a large or small amount of iron, and of melting it faster and hotter, and with less fuel; but iron melted in the cupola furnace will not make as strong or as sound a casting as iron melted in the reverberatory furnace. To overcome this disadvantage, the foundryman has adopted the theory that he will sell you a casting cheap; and if it breaks, he will sell you another one cheap. The cupola furnace has been in use for a great many years, and is almost as old an invention as the reverberatory furnace. Cupolas were first built in England and in this country, with a stationary fire-brick hearth or bottom; and a large opening was left in the front, through which the dump or refuse was drawn out with hooks in place of dumping it by dropping the bottom. The large opening in the front was filled in with sand or loam, and a plate fastened in front of it to prevent it from being blown out; and the tap-hole was put in the same as at the present time. The old style draw cupola, as it is called, is still in general use in England; and some few are still in use in this country in some of the Southern States. I saw three of them in use in a foundry in Baltimore two years ago. But the draw cupola has, as a general thing, been replaced in this country by the drop-bottom cupola, which is an American invention.

With a view of making some improvement in cupolas, foundrymen have constructed them in all shapes, and of all sizes and forms, and tuyeres have been put in in different shapes for admitting the blast into the stock. I have shown or described some of the principal cupolas in use at the present time that I have melted iron in or seen it melted in ; but I do not consider any of the new style or odd-shaped cupolas superior to the common straight cupola for melting iron, or for economy in fuel. In order to do good melting in any cupola, the lining must be kept in proper shape, as explained farther on.

CONSTRUCTION OF CUPOLAS.

When constructing a cupola, the first and most important thing is to decide where it shall be *put*. In deciding this question, there are two things to be considered ; the first is, where will it be the handiest to get the iron and fuel to it ; and the next is, where will it be the handiest to get the iron away from it. The latter is by far the most important point to be considered, especially in foundries where light work is made. It is easier to wheel pig-iron to a cupola than it is to carry molten iron away from a cupola ; and the cupola should be set as near the center of the foundry as possible, so that the iron can be carried away from it in all directions, and so make the distance to carry it as short as possible.

THE FOUNDATION .

A good, solid stone foundation should be put down for the cupola to stand upon. If the foundation is not solid, it is liable to settle when the weight of the cupola

and stock comes upon it, and may crack the bottom plate, which will make trouble. The height that a cupola should be from the floor will vary according to the class of work that it is intended for. In stove-plate foundries, where the iron is all carried in hand ladles, the average height is from ten to twenty inches, and in machinery foundries, where large ladles are used, the average height is from two to three feet. When the cupola is very low, a pit should be put in, as shown in Fig. 10, so that the bottom can be dropped and the refuse taken away easily. This pit may be put in on any side of the cupola where it will be most convenient; when put in front of the cupola, it may be covered with cast-iron plates, and the plates covered with a few inches of sand to prevent the iron flying, in case any is spilled. Cupolas may be set on brick walls or on iron columns; when the cupola is set high, the columns are the best, as they will last longer than brick, and are handier to get around. Care should be taken to not set the cupola too high, as the iron will sparkle and fly, in falling, into the ladles, and a great deal of it will be wasted in the course of time.

BOTTOM PLATE.

The bottom plate or ring upon which the cupola stands should be made of good, strong iron, and cast with strengthening ribs on it, so that it will not break when the weight of the cupola and stock comes upon it; for if the bottom plate once gets broken, it will always make trouble in putting up the doors and putting in the sand bottom, and make it more liable to cut through and run out. In small cupolas the bottom plate should only come flush with the inside of the brick lining, so as to allow the sand bottom to fall out easily when the door is dropped. In large cupolas the bottom

plate should project three or six inches inside of the brick lining, so as to make the door smaller and easier to handle; when the bottom plate projects inside of the lining, the lining should be arranged as shown in Fig. 13, so as not to give the sand bottom too much bearing, and prevent it from dropping out easily.

THE IRON BOTTOM.

The cast-iron drop door, divided into two or more pieces, is generally used for the bottom; it should be made as light as possible, so as to be easily raised. Wrought-iron doors are sometimes used on account of being lighter and easier raised; they answer equally as well as the cast-iron doors. The door or doors should be supported by a good, solid prop under them, and not by a latch that is liable to give way at any time and burn every one around the cupola. Slide bottoms are sometimes used for large cupolas; these bottoms are divided in the centre and rest upon a slide at each end; they are shoved forward into place with a bar and drawn back by a chain and windlass. The slide bottom makes a very good, safe bottom, but it is not always as convenient as the drop door. The iron bottom should be perforated with small holes, to allow the steam and gas from the sand bottom to escape without passing up through the molten iron.

CAISSON OR SHELL.

The caisson for cupolas should be made out of boiler iron, or heavy sheet-iron bars of angle iron should be riveted around on the inside of the caisson about three or four feet apart, so as to support the lining, and in

case part of it gives out, to admit of its being taken out and repaired without taking down the whole lining; the angle iron also stiffens and strengthens the caisson, and is better than brackets. The old style, cast-iron stave caisson, with a brick stack, is still made and used in some parts of the country. They are more expensive than the boiler-iron caisson, and are not near so good, as the staves are liable to break from the expansion and shrinkage, and crack the lining and allow the blast to escape. The caisson should be well painted with coal tar, to prevent its rusting and make it last longer. The caisson will often rust through, and give way near the bottom in a short time. This is caused by the lining sweating and the moisture settling at the bottom; and by putting in a heavy sand bottom and allowing no way for the moisture in the sand to escape, this keeps the lower courses of brick always wet and damp, and the rust soon eats through the caisson. This trouble may be overcome by laying the first two or three courses of brick out one or two inches from the caisson, so as to form a small air chamber all around the bottom of the cupola. The bottom of the caisson should be perforated with small holes to supply this chamber with fresh air, and allow the steam and moisture to escape.

CUPOLA STACK.

The diameter of the stack should not be more than one-half the diameter of the caisson, so as to concentrate the heat. It should be drawn in just above the charging door, so as to throw the heat downward on the stock. The stack should be high enough to give the cupola a good and even draft; a cupola with a good draft will melt better and make softer iron than one with a poor draft, for the nearer we can come to a nat-

ural draft the better for the iron. More power will be required to drive the fan or blower, when the cupola has little or no draft, for the blast has to be *forced* clear out at the top of the stack.

I consider the stack one of the most important parts of the cupola.

THE SCAFFOLD.

The scaffold should be built large enough to keep stock sufficient for a rainy day or an accident, and have plenty of room to get around. The floor should be made of cast-iron plates, properly fitted together, so as to be fire-proof, and easy to shovel scrap or fuel off. The scaffold should be cleaned up, and the floor swept every day, so as not to get too much dirt and sand into the cupola.

CHARGING-DOOR.

The charging-hole should be large enough, and so arranged that the melter can throw in the iron with ease, and at the same time see where it lights and how it lays. The door should be made to fit close, and lined with fire-brick to prevent it from warping. A cast-iron door frame, filled in with fire-brick, makes the best door for a cupola. Two charging-holes are sometimes put in, in a large cupola (one on each side), for convenience in charging the stock. Cupolas are arranged in this way at James L. Haven & Co.'s novelty foundry in Cincinnati, Ohio, and at Smith & Sons' pipe foundry in Pittsburg, Pa. Two charging-holes are generally put in, in all large cupolas where coke is used as a fuel. See CAPACITY OF CUPOLAS.

ELEVATORS.

There are a great many ways of getting the stock upon the scaffold. At some foundries, the iron and fuel is all thrown upon a platform, and from there thrown upon the scaffold. This is a very poor way of getting up the stock, as it makes a great deal of unnecessary handling of the iron, and there is a great deal of the fuel wasted by being broken up fine, so that it is not fit for use in the cupola. Other foundries have a run-way, and wheel up all the stock in wheelbarrows. This is a better way of getting up the stock than throwing it up; but it is very hard work wheeling up iron, especially if the run-way is very steep, as it generally is. In most of the large foundries they have steam elevators for taking up the stock. These elevators are very handy, and take up less room than a run-way does, and the saving in labor will soon pay for the expense of the elevator. The expense of running an elevator is very little; for they are only run for an hour or two each day. There are several different kinds of elevators in use in foundries; but the principal one in use is the common straight steam elevator. Where it is desirable to carry the iron some distance, as well as elevate it, other kinds of elevators are used. In one foundry that I visited, where the stock was all kept in the cellar, an inclined-plane elevator was used for taking the stock upon the scaffold. This elevator was made by running two endless chains over two shive pulleys at the top, and two at the bottom, and fastening shelves or buckets on to the chains. The stock was put on at the bottom and dropped off at the top as it went over the shive pulleys. This makes a very good elevator, and is better adapted to some foundries than the straight elevator. In other foundries an inclined-plane railroad is used, with a car drawn up by a rope

or chain. This style of elevating the stock is very good where it is kept in the yard, at some distance from the foundry, and where there is plenty of room; but it is not so well adapted to foundries where room is an object.

SCALES.

A good pair of scales should be kept on the scaffold, and all the stock that goes into the cupola should be weighed accurately. The scales should be swept off after every draft, and kept in good order. Most foundrymen think that any old scales are good enough for the scaffold, because they neither buy nor sell by them, but are merely dealing with themselves. It is very true that they are only dealing with themselves, and they are cheating themselves out of hundreds of dollars' worth of fuel every year. Some foundrymen do not have any scales at all on the scaffold, but depend upon the melter guessing at everything he puts into the cupola. Guessing at the amount of stock charged is often the cause of slow melting, of dull iron, of irregular melting, of running short of iron, and of burning out the lining in a short time, etc. There is not a foundryman in the country, who depends upon the melter to guess at the weight of the stock he charges, but what could save enough in one year to buy two or three pair of good scales by having his stock accurately weighed. There is nothing gained by having a good pair of scales on the scaffold, unless you see that the stock is carefully weighed, and no more fuel used than is actually necessary.

L I N I N G .

A two-inch lining is heavy enough for a small cupola, and six or eight inches is heavy enough for any size cupola. In laying up a lining, the brick should be fitted closely together, so as to use as little mortar between them as possible; for, if too much mortar is used, it will crumble and fall out when the heat strikes it, and will leave openings through which the blast will escape. The best way to lay up a lining, is to have a bucket full of thin mortar or grout, and dip each brick into it as it is laid up. Each course of brick should be grouted between the brick and the caisson as soon as it is laid; if you do not grout between the brick and the caisson until two or three feet of brick have been laid up, the grout may not run down to the bottom, and will make a poor lining. When the lining is built three or four inches from the caisson, it may be filled in with molding sand properly tempered for molding, and rammed in solidly. This sand is better than grout, for it will not crack when it dries, as grout will. Stone lining should never be put in, except when it is impossible to get brick, as they are expensive to lay up, and cannot be laid without using a great deal of mortar, which will soon fall out from the excessive heat, and the stone will crack from being suddenly cooled when the bottom is dropped. Common brick will stand the fire better than stone; the softer brick should be used. The lining should project out one or two inches just over each tuyere, to prevent the molten iron from dropping into the tuyeres. Some melters think that the caisson is air-tight, and the blast cannot escape, and it does not make any difference if it does get out through the lining. These melters should remember that they are not trying to melt down the *lining*, but the *stock*, and all the blast that escapes up through and back of

the lining, is cut off from the stock and is lost. A good fire-brick lining should last from one to two years, according to the amount of iron melted and the way the lining is daubed and kept up. There is nothing gained by keeping a lining in too long, as it will become shaky, and the blast pass up through and behind it instead of passing through the stock, and more fuel is required to make hot iron.

FIRE-BRICK.

For lining cupolas and furnaces, the selection of a proper description of fire-brick is a matter of considerable importance, and the foundryman should be careful to select the best brick regardless of expense, for a few dollars more on the thousand is nothing when compared with the consequences of using cheap and inferior brick, which would be costly at any price. From the great wear and tear upon them, and from the delay and loss caused by the often-repeated stoppages for repairs, it is the wisest and the best economy to always use the best fire-brick that can be procured. I shall not enter into the merits of the fire-brick manufactured by different companies, but I should recommend the use of the white or softest brick as being the best for standing the fire; and in lining up a cupola, the softest brick should always be selected for the bottom, where the heat is greatest, and the hard ones for the top, where the lining is liable to be struck and broken by throwing in the iron and fuel. The wedge or circular brick is better for lining cupolas than the straight brick, as they can be laid closer together and require less mortar, and will make a better and more solid lining that will last longer.

T U Y E R E S .

The tuyeres in a cupola should be put in at equal distances apart, and they should be arranged so that each one of them will admit an equal amount of blast into the cupola. A tuyere should never be put into a cupola directly over the tapping hole, and if the tuyere is a continuous one, as is the McKenzie, it should be stopped up over the tapping hole. The height of the tuyeres from the sand bottom will vary according to the class of work that the cupola is intended for. In stove foundries, where the iron is drawn out as fast as it is melted, the tuyeres are put in very low; but in a machinery foundry, where it is desirable to hold the molten iron in the cupola for a large casting, the tuyeres are put in higher; but the low tuyeres are the best for making hot iron and for continuous melting. In all of our large stove-foundry cupolas the tuyeres are put in only two or three inches above the sand bottom, and in some of them the tuyeres are so low that the sand bottom is slopped clear up to the bottom of the tuyere. When the tuyeres are put in low, the melting point of the cupola is lower, and less fuel is required for the bed, and the bed is easier to keep up in a long, continuous heat. The tuyeres should never be put in more than ten or twelve inches above the sand bottom, for the cupola will not make as hot iron, and it is almost impossible to keep the bed up for a long, continuous heat. The old style of having one tuyere hole above another, and raising the tuyere pipes as the cupola fills up with molten iron, and stopping up the lower tuyere holes with clay, has generally been abandoned as a failure; for, after the cupola has been filled up with molten iron in this way, and the iron drawn out, the stock will generally settle so that the cupola is of no account for further melting; and for a long, continuous heat it is better to draw out the iron as fast as it is melted, and

hold it in a ladle, if necessary. I should recommend low tuyeres in all cases for making hot iron and saving fuel. The foundryman must use his own judgment as to how many tuyeres to put into his cupola, but he should put in enough to distribute the blast equally through the stock, and no cupola should have less than two tuyeres or one continuous one.

DIFFERENT SHAPED TUYERES.

There are a great many different shaped tuyeres or openings in the lining for admitting the blast into the cupola, and I will now describe some of the principal ones in use that give good satisfaction. The oldest tuyere in use is the common round tuyere, and it gives good satisfaction when put in right.

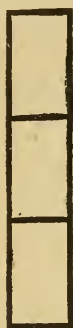


FIG. 1.

The tuyere (fig. 1) is a cast-iron frame, with a slot or opening in it two inches wide, by ten or twelve inches long. This tuyere was in use in Davis' stove foundry in Cincinnati, Ohio, in 1874, and gave good satisfaction.

The T shaped tuyere (fig. 2) is a cast-iron frame, with a slot or opening at the bottom two inches wide by eight inches long, with an upright slot two inches wide by ten or twelve inches long. This tuyere was in use in the stove foundry of Readway & Burton, in Cincinnati, Ohio, in 1875, and appeared to give good satisfaction.

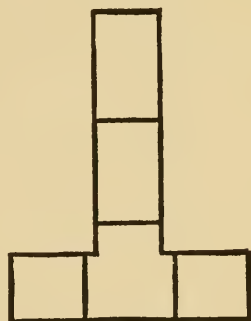


FIG. 2.

The tuyere (fig. 3) is a slot one inch wide, running one-third of the way around the cupola on each side, with four upright slots, each one inch wide and ten or twelve inches high. This tuyere may be made as a

cast-iron frame, or be formed in the brick lining; it was in use in the foundry of Griffith & Wedg, Zanesville, Ohio, in 1873, and gave good satisfaction. A

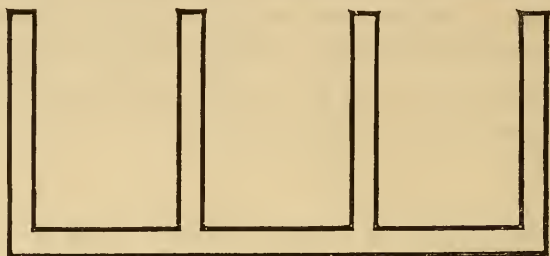


FIG. 3.

cupola forty inches in diameter, with two of these tuyeres in, would melt five tons of iron per hour.

The tuyere (fig. 4) is a slot tuyere one inch or more wide, and running one-third of the way around the cupola on each side; or it may be connected and form a continuous tuyere all around the cupola. These tuyeres are made by taking two iron plates and laying small blocks of iron between them, as shown in fig. 4.

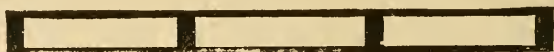


FIG. 4.

This tuyere was in use in a hollow-ware foundry in Allegany City, in 1874, and appeared to give good satisfaction.

The tuyere (fig. 5) represents a tuyere that is in use in some of the foundries in Philadelphia and New York. It is said to give good satisfaction.

The tuyere (fig. 6) is an oval shaped cast-iron tuyere; it is generally laid flat, as shown in fig. 6, and is made large or small, to suit the size of the cupola. This tuyere is in general use in the Troy and Albany stove foundries, and is said to be a good tuyere.



FIG. 5.

The tuyere (fig. 7) is the Lawrence patent reducing tuyere. This tuyere is made of cast-iron, and is a cast-iron frame with a large opening at the bottom, and an upright slot, reduced to

nothing, at the top. The large opening is about three inches in diameter, and the slot is ten or twelve inches long. This slot is one inch wide at the bottom, and tapers to nothing at the top. This tuyere gives good satisfaction when it is in proper shape; but the upright slot is liable to collapse from the heat, as it is too small to admit enough blast to keep it cool. This tuyere would do better if it was made of fire-clay.

The tuyere (fig. 8) is a reducing tuyere, and is merely one round opening above another. They are put in two or more inches apart, and three or more may be put in,



FIG. 6.



FIG. 7.



FIG. 8.



FIG. 9.

in a row, and each one gets smaller towards the top. This tuyere is used in the Truesdale patent cupola; but I do not know whether Mr. Truesdale has a patent on the tuyere or not.

The tuyere (fig. 9) represents a triangle-shaped tuyere that is used in some of the Cincinnati foundries; it is a cast-iron frame, set in the brick lining, and may be made as an equal triangle, or it may be a little higher than it is wide, so as to bring it up to a sharp point at the top. I think this a good tuyere, for the sharp point at the top cuts the blast at the top, and it is not so liable to form a bridge over the tuyere as the round or oval-shaped tuyere is; and I should recommend this tuyere in preference to all others, especially for small cupolas.

CAPACITY OF CUPOLAS.

There are so many things that control or affect the working of a cupola, and the melting of iron, that it is almost impossible to make any estimate of the size that a cupola should be to melt any given amount of iron. The shape of the cupola, the size and number of tuyeres, the pressure of blast, the height and draft of the cupola, the way in which the cupola is daubed and made up, the way the bed is burnt and the stock is charged, and the kind of iron melted, all make a difference in the melting capacity of a cupola. From practical observations in melting with both coal and coke, I have made out the following table as an approximate of melting capacity, for the guidance of foundrymen who may wish to put up new cupolas.

Diameter in inches.	Height in feet.	Size of door in inches.	Least amount should be melted.	May be melted with ease.	May be melted by careful charging.	Extreme melting capacity.	Tons per hour.
15	6 to 8	15 x 18	ton. $\frac{1}{2}$	ton. 1	ton. $1\frac{1}{2}$	ton. 2	$\frac{1}{2}$
20	8 to 10	20 x 24	1	2	3	4	1
24	9 to 10	24 x 28	2	3	5	6	$1\frac{1}{2}$
30	10 to 12	28 x 30	3	5	8	10	3
40	11 to 13	28 x 30	5	9	13	16	5
50	12 to 14	30 x 36	8	14	20	23	7
60	13 to 15	40 x 30	11	16	22	25	8

NOTE—The pressure of blast depends upon the volume of blast.

The above table of melting capacity is only intended for the common straight cupola. The diameters given are the diameters inside of the lining. A cupola should never be made less than fifteen inches in diameter; for the stock will hang, and the cupola will bung up very easily, and will be more bother than it is worth. If a

cupola is over sixty inches in diameter it should be drawn in at the tuyeres, as the McKenzie and Lawrence cupolas are, so as to throw the blast to the centre of the stock. I do not consider the melting capacity of a cupola to be the largest amount of iron that can possibly be forced through it in any shape, but the amount that can be melted with ease, and the cupola left in good shape when dumped.

HIGH AND LOW CUPOLAS.

From the bottom plate to the bottom of the charging-door is the height of the cupola, and the top of the charging-door is the bottom of the stack. It is claimed by some of the theory-melters that five feet is too great a height for a cupola, and that the best and most economical melting can be done in a cupola of three or four feet in height; they claim that there is no other advantage in having a high cupola than having a large body of fuel on fire at once; this they claim may be effected to more advantage by a greater diameter, and that the low cupolas, even as low as three feet, do better melting than high ones. This theory may be very good for small cupolas, where it is only desirable to run off a heat of a few hundred of iron, but it will not do where it is desirable to run off a large heat in a few hours and make hot iron. Just imagine some of our large stove foundries, that melt as high as twenty tons of iron in one cupola, melting that amount of iron in a cupola only three feet high; it would be utterly impossible to run off a heat in any reasonable length of time, or to make hot iron. If we increase the diameter of the cupola too much, the blast cannot be forced into the centre of the stock, so that we cannot gain the same advantages that we could by increasing the height of

the cupola ; yet I think this theory of low cupolas and large diameters is the correct theory for building small cupolas ; for, if we build a cupola of a very small diameter and great height, the stock is liable to hang on the lining, and we cannot force it down ; but if the cupola is low and of a large diameter, it will not be so liable to hang, and if it does hang, we can poke it down with a bar ; and I think that a cupola with a small diameter should be low, and its height increased as the diameter is increased. I have found, by accurate comparative tests in melting with coal and coke, that high cupolas do faster and more economical melting than low ones, because more stock can be put into them at once, and it will be getting hot from the heat that otherwise would escape up the stack ; the iron will be hot and in a better condition to melt when it comes down to the melting point, and it will make a softer iron ; there will be more of a downward pressure, and the blast will be more confined, and the heat concentrated. If the cupola is low, we cannot put so much stock into it at once, and there will be less of a downward pressure ; the blast will not be confined, but will pass through the stock, carrying with it a great deal of unconsumed gases, and more fuel and more time will be required to make hot iron. I found, by careful tests made in Philadelphia, Pa., in 1874, that a cupola forty-five inches in diameter and fourteen feet high, would melt as much iron in an hour (with one per cent. less coal), and would run off as large a heat as a cupola sixty inches in diameter and ten feet high, with the same pressure of blast.

I found by careful tests made in St. Louis, Mo., in 1875, that a cupola fifty inches in diameter and thirteen and a half feet high, would melt fifteen tons of iron (with one per cent. less coke), in the same time that a cupola fifty inches in diameter and nine feet high would melt ten tons of iron with the same pressure of

blast. The above tests were not made in any one foundry, but were comparative tests between one foundry and another, and go to show why one foundry can sell castings cheaper than another.

I should recommend high cupolas in all cases where the diameter is large, and more especially where coal is used for fuel in melting; for coal will break and spall off when suddenly heated. This fine coal or spall will settle down through the stock (especially if the coal used in melting is large), and is not burnt, but will settle down and lay over the tuyres, and will gather cinder and prevent the cupola from melting; and when the cupola is picked out, these small pieces of coal will be found mixed with the cinder, appearing as if they never had been touched by the fire. It is impossible to entirely overcome this mechanical destruction of the coal, but it may be overcome to a certain extent by high cupolas; for, if the cupola is high, more stock can be put into it at once, and the coal will be heated up gradually and will not be so liable to crack and fly from the heat. On the other hand, if the cupola is low, very little stock can be put into it at once, and after the blast is on for a short time, the stock becomes hot clear up to the charging-door, and the next charge of coal is struck by an intense heat as soon as it is thrown in, and it cracks and flies, and we have a mechanical destruction of the coal in place of a chemical combustion. While I would recommend high cupolas for melting iron with coal, I would also caution the foundryman against too great a height, for we may get a cupola so high, that throwing in the iron will damage the coal more than heating it suddenly would do. A few plates should always be put in on top of the coal, to protect it from being broken up by throwing in the heavy iron.

M c K E N Z I E C U P O L A .

Fig. 10 represents a sectional view of the McKenzie patent cupola. This cupola is generally made oval in form instead of round; the lining is contracted just above the tuyeres, and is supported by an apron bolted on to the caisson. This apron projects inward and forms an opening or air chamber all around the cupola, as indicated by *B B*. This air chamber is supplied with air from the blast pipes, *D D*; the tuyere is a continuous one, and is merely an open slot, about two inches wide, running all the way around the cupola, as represented by the letters *A A A*. This tuyere is supplied with blast from the air chamber, *B B*. This cupola is in use in a great many foundries, especially in stove-plate foundries, and it will do very good melting when kept in proper shape, as shown in Fig. 10, but is very liable to get bridged out or collect cinder over the tuyere; and if the melter does not keep the cinder chipped off, it will soon get the lining in the shape shown in Fig. 11, which shape will reduce the melting capacity of the cupola and cause it to bridge over in a short time. To avoid this, the melter should be careful to keep the lining in as near the shape shown in Fig. 10, as possible. Small cupolas, constructed on the McKenzie plan, are generally a failure on account of bridging over above the tuyere, and even the large ones have in some cases been condemned on that account; but the large McKenzie cupolas will work well, if kept in proper shape, but where this style of cupola will not work well, the apron can be taken out and the cupola made into a common straight one. I have seen one of these cupolas at the Greenwood Stove Works, in Cincinnati, Ohio, out of which the apron had been taken and six round tuyeres put in; one at each end and two on each side at equal distances apart; this arrangement worked better in this shop than the apron and continuous tuyere.

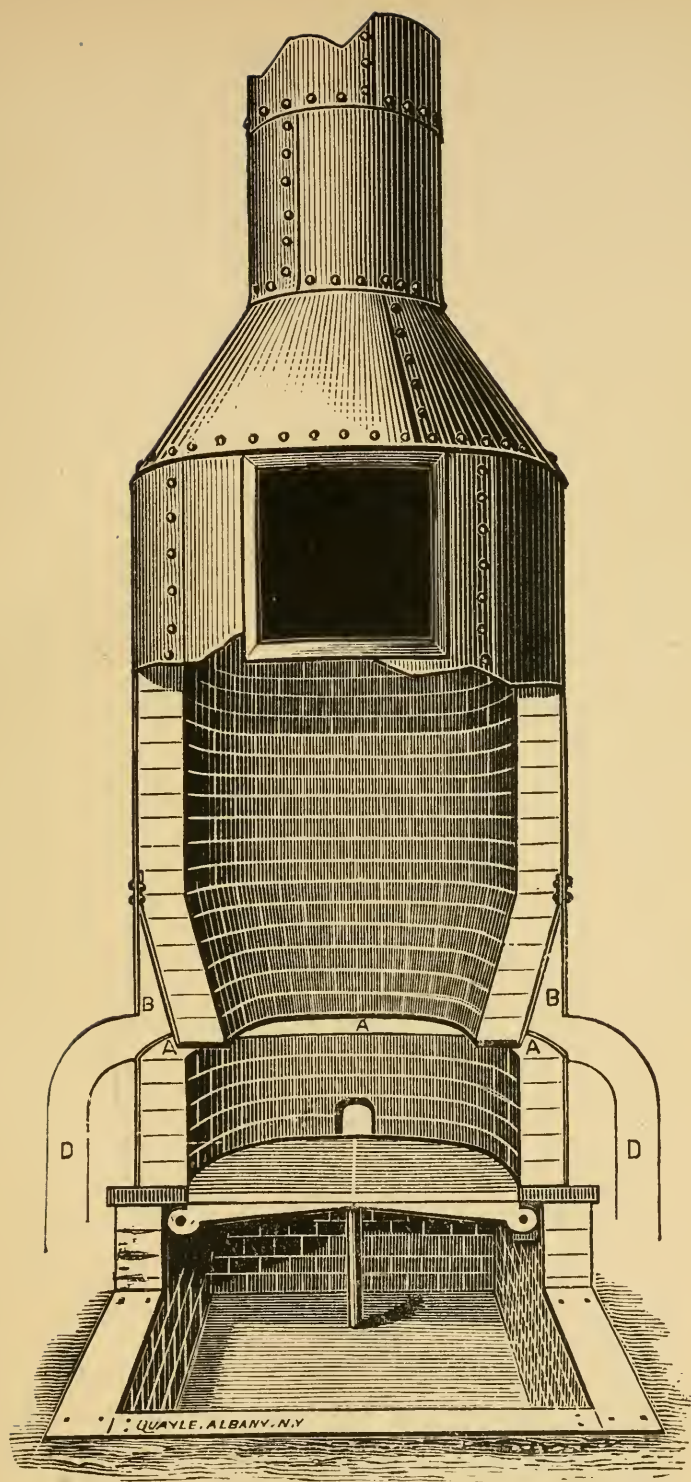


Fig. 10.

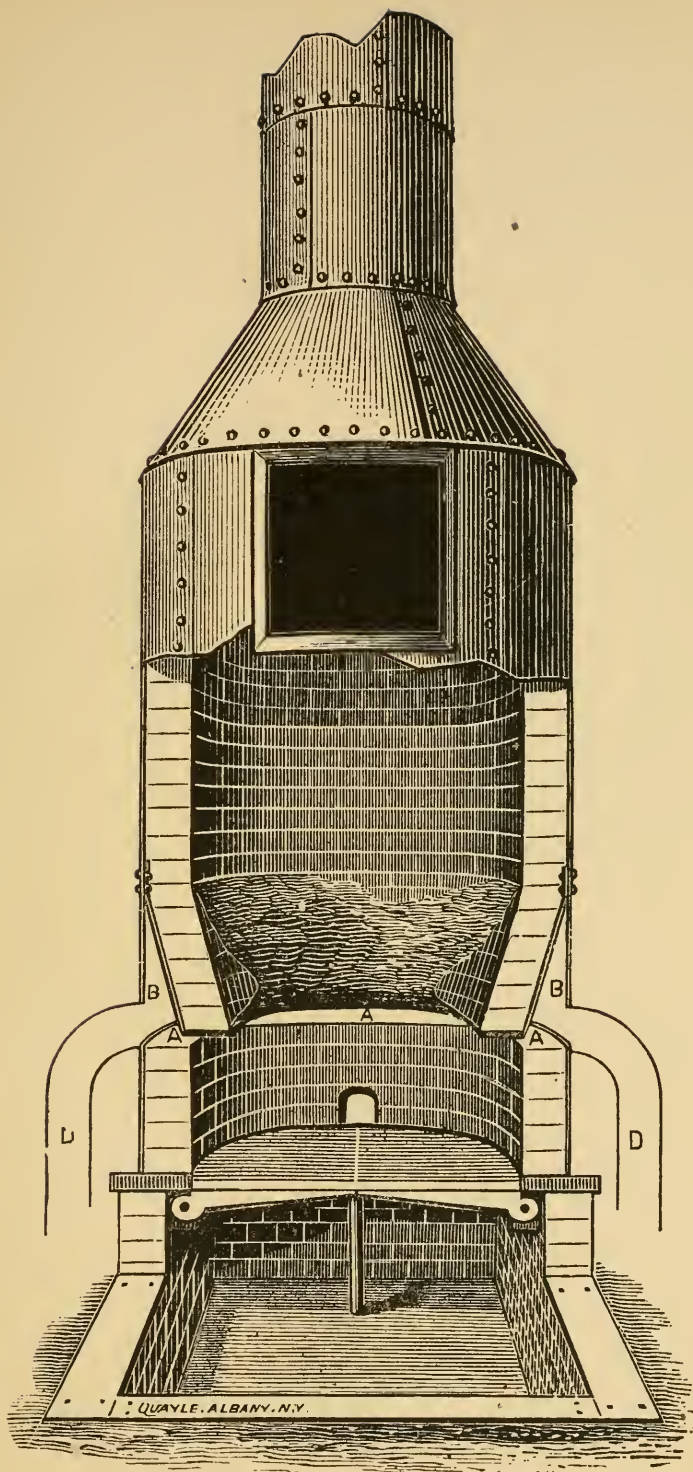


Fig. 11

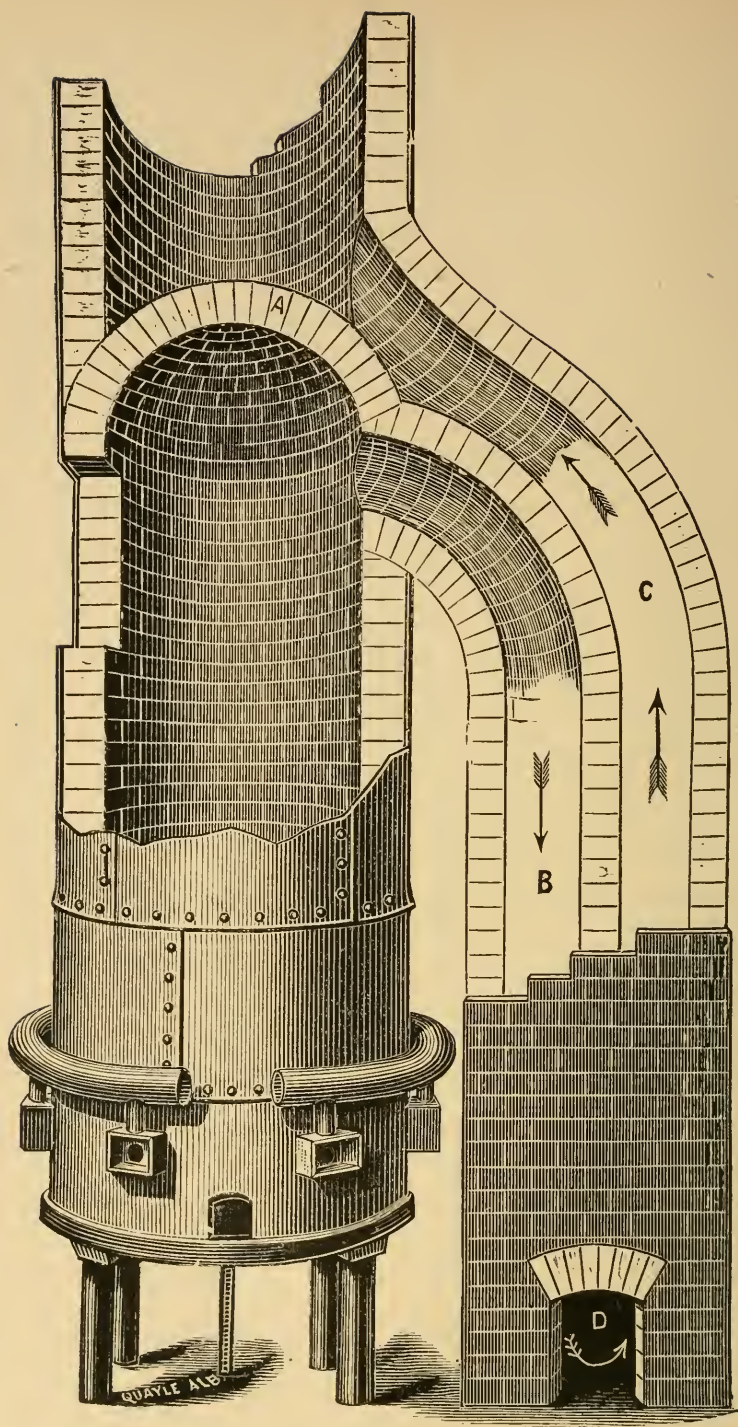


Fig. 12.

RETURN-FLUE CUPOLA.

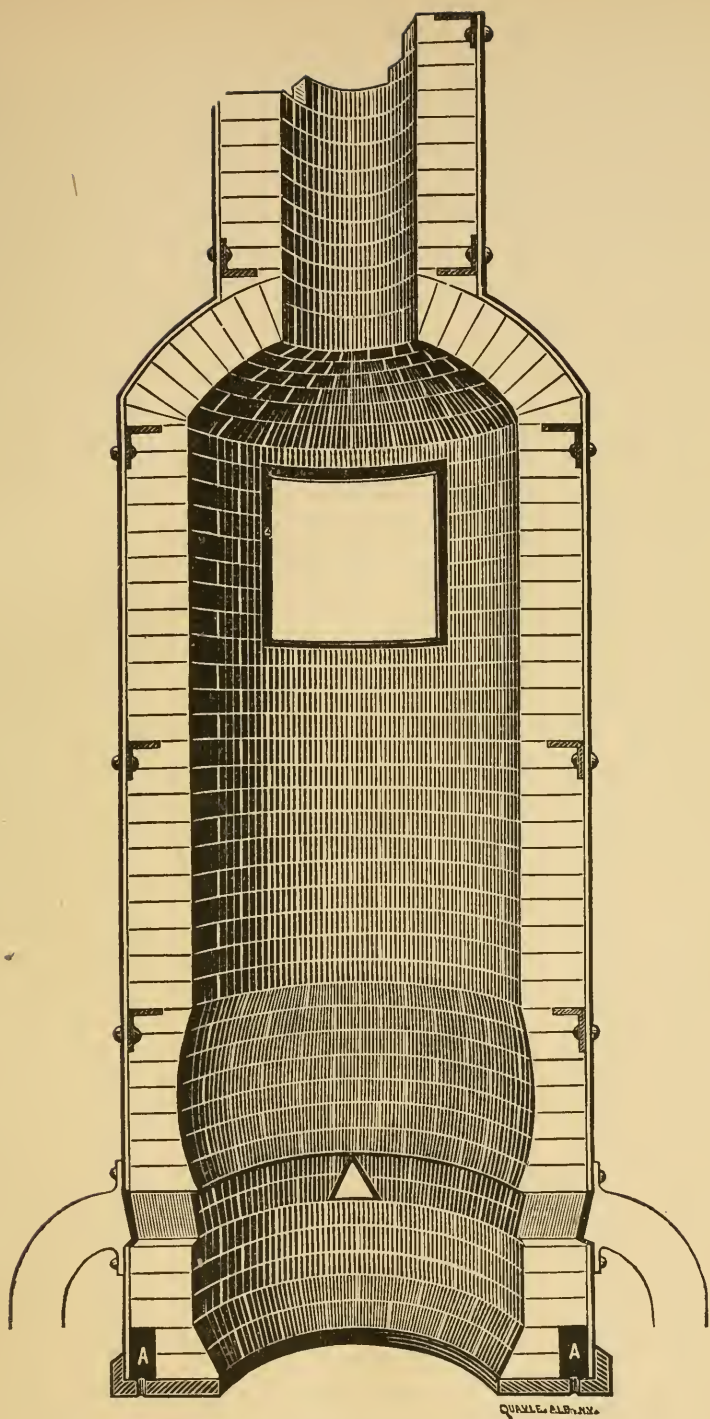
The return-flue cupola, Fig. 12, was arranged and erected by Mr. John O'Keefe, superintendent of Perry & Co.'s Stove Works at Albany, N. Y., with a view of saving fuel and catching the sparks from the cupola. With this view, the arch *A* was built across the cupola just above the charging-door, so as to throw the heat down upon the iron, and the flue *B* was led out of the cupola just under the arch *A*, and brought down to the floor and returned to the cupola above the arch, and when the cupola was in operation all the waste heat from the fuel passed up and struck the arch *A*, and was again thrown down on the iron or forced through the flue *B*, as indicated by the black dart. At the bottom of this flue it turned as indicated by the white dart, and passed up the flue *C*, and again entered the cupola above the arch *A*. As the flame passed down the flue *B*, and turned to pass up the flue *C*, all the cinders and sparks were deposited at the bottom of the flues, and were removed through the door or opening *D* as often as it became necessary. This cupola was a success so far as the catching of the sparks was concerned, but little or no fuel was saved by it; for, after the arch had been put in, the cupola threw the flame out at the charging-door when the blast was on, so that it was impossible to charge the stock, and it became necessary to make a small opening through the top of the arch *A*, so as to admit of the escape of part of the flame. Had this cupola been high enough, so that all the stock for the heat could have been charged before the blast was put on, and the charging-door closed up tight, there is no doubt but what considerable fuel would have been saved by this arrangement. Several different kinds of spark-catchers have been used for cupolas, but this one is the best I have seen in use. A cheap spark-catcher

for a cupola can be arranged by taking a round cast-iron plate nearly as large in diameter as the diameter of the stack, and hanging this plate in the stack near the top of it; the sparks go up and strike the plate, and are again thrown down into the cupola. This plate will be burnt up in the course of time, and must be replaced by a new one; but when a cupola is constructed as shown in Fig. 13, no spark-catcher is needed.

STRAIGHT CUPOLAS.

I have seen and melted iron in almost all of the odd-shaped cupolas that are in use at the present time, but I have not found any of them superior to the common straight cupola, either for fast melting or for economy. It is true that some of these cupolas require a little less fuel for the bed than the straight cupola does; but what is saved in the bed has to be added to the charges in a large heat, so that nothing is saved in the long run. Yet to do good melting, either in an odd-shaped cupola or a straight one, the lining must be kept in proper shape.

In fig. 13, I have represented my idea of a perfect cupola for melting iron. In this illustration I have shown how the bottom plate should project inside of the lining in a large cupola, so as to make the bottom doors smaller and easier to handle. I have shown how the lining should be sloped out to the edge of the bottom plate, so that the sand bottom will all fall out when the iron bottom is dropped. This offset also helps to support the stock, and takes part of the weight off of the iron bottom. The caisson or shell of a cupola will often rust off, and give way around the bottom. This is caused by the lining sweating, and the moisture settling to the bottom, and by putting in a heavy sand bottom,



QUAYLE & SONS

Fig. 13.

and providing no way for the moisture in the sand to escape; this moisture keeps the lower courses of brick always damp, and causes the caisson to rust off in a short time. I have shown in this illustration how this may be avoided by laying the first two courses of brick out one or two inches from the caisson, so as to form a small air-chamber all around the cupola, as represented by the letters *A A*. Small holes should be put in around the bottom of the caisson, or through the bottom plate, to supply this chamber with fresh air, and allow the moisture to escape. In this illustration, I have shown a triangular-shaped tuyere; this shaped tuyere, I think, is the best in use, especially for a small cupola; for it comes up to a sharp point at the top, and is not near so liable to bridge over as the round or oval-shaped tuyere. I have shown a hollow place in the lining of this cupola, just above the tuyeres, which indicates the melting point of the cupola. If a cupola is lined up straight, it will burn out hollow at this point in one or two heats; and in daubing up the cupola for a heat, it should never be daubed up straight or too full at this point, but should be left a little hollow, as shown in fig. 13. I have shown how brackets or angle iron should be riveted on to the caisson every three or four feet, so as to support the lining, and admit of the lower part, where the lining burns out the fastest, being taken out and replaced without taking down the whole lining. The lining can be taken out and replaced without the brackets by taking out one side of it at a time, and replacing it with the new lining before taking out the other side; but after a lining has been taken out and replaced in this way it always settles, and cracks, and injures the lining. I have shown how the stack should be reduced to one-half or less the diameter of the cupola, and how it should be drawn in by an arch just above the charging door. I think that a cupola contracted suddenly, as this one is, is better than to have

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a long-tapered contraction, for in this cupola the heat comes up and strikes the arch, and is thrown down on the iron; the sparks strike this arch, and are not so liable to be carried out at the top of the stack as in a long contraction by reducing the diameter of the stack. In this way the heat is more confined and equalized, and will make a more even iron than a cupola with a large stack, where the heat escapes freely up the stack.

DAUBING THE CUPOLA.

The most important thing in the melting of iron in cupolas is the proper construction of the cupola; and the next important thing is to keep the lining in proper shape. I have shown, in fig. 13, what is the proper shape,—which is a slight projection over each tuyere, to prevent the iron from dropping into the tuyere, and a hollow in the lining, or increased diameter of the cupola just above the tuyeres. This hollow place in the lining may be a little higher than I have shown in this illustration, as explained under the head of “The Melting Point;” but in putting in a new lining, it is not necessary to form this hollow in the lining, for the heat will soon cut it out at the melting point; and in daubing and making up the cupola for a heat, the lining should always be left slightly hollow at this point, as shown in fig. 13.

Some melters, who do not thoroughly understand their business, think that, when the lining burns out hollow at the melting point, they must make it up straight with daubing, or the lining will burn through, and the iron will run out through the caisson; and they will daub on a belt of mud two or three inches thick all around the cupola, as shown in the sectional view of a

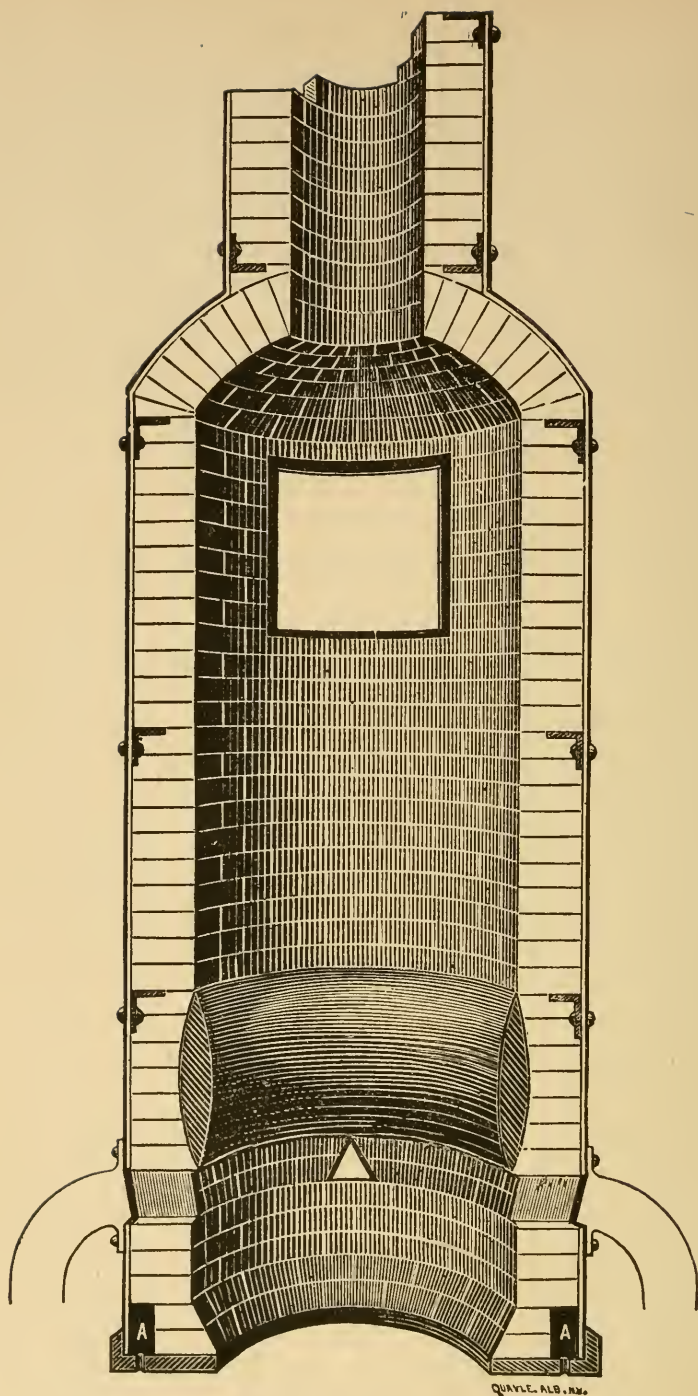


Fig. 14.

cupola (fig. 14). This belt of mud is not only made flush with the lining, but it often projects out farther than the lining, and by it the diameter of the cupola is decreased at the point where it should be the largest. The daubing for cupolas is generally made of common clay, mixed with a little fire-sand or sharp-sand. This daubing will not resist the heat like fire-brick or fire-clay, and the heat is more intense at this point than at any other in the cupola; and this daubing, if put on too thick, will melt and be converted into a cinder or slag; and this slag will run down and be chilled over the tuyeres by the cold blast, and will bung up the cupola in a short time; or this mud belt may break loose from the lining, as shown in fig. 15, which illustration represents a sectional view of the interior of a cupola that I saw at Richmond, Indiana, in 1875. This cupola was about thirty or thirty-five inches in diameter, and the average heat melted in it was about four tons; the melter, in charging, used too much coke in the bed and between the charges of iron. This caused slow melting, which was very hard on the lining, and cut it out badly at the melting point; and when chipping out, and making up the cupola, the melter would chip out all the cinders and slag until he came to the brick, and in knocking off the cinders he would jar and crumble the face of the brick; he would then daub on a belt of mud two or three inches thick all around the cupola, as shown in fig. 14. This mud was too heavy to hang on the brick, and when it was heated slowly the moisture was all forced back against the brick lining, which moistened the mud at that point, and caused it to break away from the lining; and it would then settle down in a heap over the tuyere, as shown in fig. 11; but when it was heated rapidly, the heat would bake the outside of it and prevent it from squatting down in a heap. The moisture in the mud was converted into steam, and was forced back against the

brick, where it would be partially condensed; and the water would soften the mud, and the steam would force it off from the lining at the top, and the fuel and iron would get down behind the mud and force it down into the cupola, so as to bridge it over above the tuyeres. One day, while I was at this foundry, the cupola melted very slow, and when the heat was about half off the iron began to run out at one tuyere, and no iron at all could be gotten out at the tap-hole. The cupola continued to melt in this way for a short time and then stopped altogether; and the bottom was dropped. On examining this cupola the next morning, I found it to be in the shape shown in fig. 15. The belt of mud had broken loose at the top from the brick lining, and the fuel and iron had gotten down behind it, and forced it down into the cupola, so that it formed a complete bridge over it just above the tuyeres, with only a small opening in the centre. All the fuel around this opening had been consumed, and the iron came down and lodged on this bridge of mud; and it was here struck by the cold blast, and the melting stopped. On the one side the bottom of this mud belt still hung to the lining, but on the other side it had broken loose altogether, and had sank down below the top of the tuyere and on this side some little iron had been melted above the mud bridge, and came down and run out at the tuyere. This melter always had trouble in dumping his cupola, and he generally had to poke and pry at it with a bar for one or two hours every heat before he could get it down; and sometimes he would have to work at it until eight or nine o'clock at night. All his trouble was caused by too much daubing. The lining would be cut in holes every heat, and the melter had to put in a few new brick after each heat. All these holes that were cut in the lining were caused by using too much daubing, and the daubing breaking loose from the lining and settling down in such a shape as to

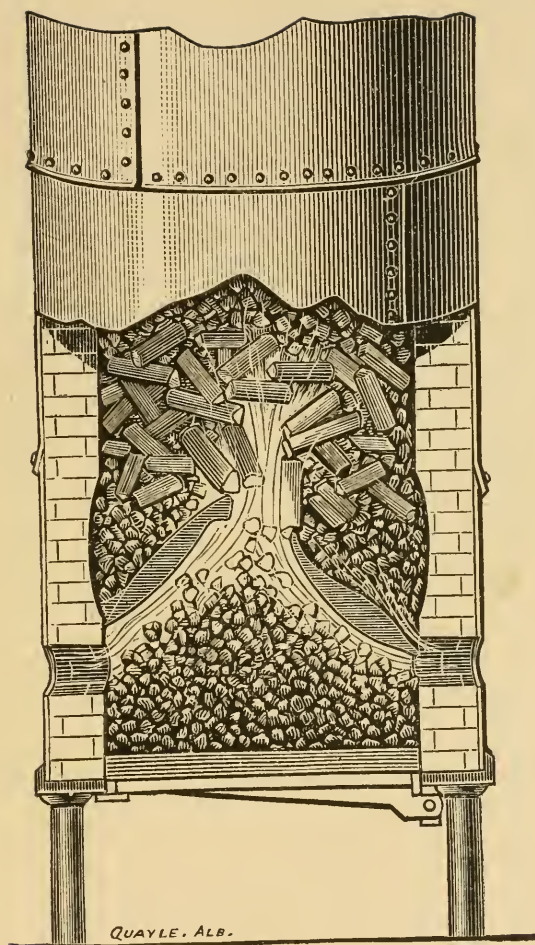


Fig. 15.

throw the blast and heat against the lining in spots, instead of having an equal heat all around.

This cupola had to have about two or three feet of new lining put in, just above the tuyeres, every two weeks, and the melter, to protect this new lining, would always daub an inch or two of mud upon it; this mud, instead of protecting the lining, was the cause of its burning out, for it would break loose from the new lining and settle down so as to prevent the free working of the cupola, and concentrate the heat upon the lining and melt it down instead of melting the iron. The melter in this foundry had made the proprietor believe that the cupola was too small to melt four tons of iron, and that it was worn out, which was the cause of all his trouble with it, when really the whole trouble was, that the melter did not understand his business, and his ignorance was costing him a great deal of extra labor and costing the foundry company five dollars or more every day for extra fuel, fire-brick and clay. Yet the lining of a cupola will be burnt out at the melting point a little every heat, and if the melter does not replace it, it will burn through to the caisson and the iron will run out through it. To prevent this, the melter must have recourse to daubing, but he should be careful not to use too much or too little daubing, and he should keep between the two extremes, and to do this, he should not daub on more than a half inch or an inch of daubing at any one place, and if this amount of daubing will not keep up the lining, it cannot be kept up by putting on more than that amount; for after he gets beyond that amount, the daubing is too heavy to hang on to the lining, and it breaks loose and does more harm than good; even one inch of daubing is too much to put on all around the cupola. When chipping out the cupola, the melter should not chip out all the cinder until he comes to the fire-brick, but he should merely chip out enough to get the cupola in

proper shape ; for this cinder has been oxidized by the heat, and in many cases it will stand the fire better than the new daubing. If a cupola cannot be kept up by putting on a small amount of daubing, then there is something wrong, and the melter should at once find out what the trouble is, which may be in his manner of charging in the tuyeres, or in the blast : for if the iron is charged high in the centre it will throw all the fuel to the outside, and will cut the lining worse than when charged level ; and if the stock is charged uneven, it may be the cause of cutting out the lining in holes ; if the blast is too sharp and cutting, it will be hard on the lining ; if the tuyeres are not put in at regular distances apart, they may cut the lining badly by throwing the blast and heat against the lining in spots. When the melter finds his lining hard to keep up, he should regulate his mode of charging ; if that does not do any good, then he should vary the blast ; if that does no good, then he should change the shape, size or place of the tuyeres.

SWIVEL CUPOLA.

The swivel cupola, fig. 16, is a very handy little cupola for small work, and is in use in a great many small foundries. In constructing this cupola, four iron columns are used to support the stack, which is set upon an iron plate on top of the columns. The stack may be made of boiler plate and lined with fire-brick, as shown in fig. 16, or it may be built of common brick ; two cross-bars are bolted on to the columns, and the cupola is hung on two swivels, which rest on the cross-bars ; the top of the cupola does not touch the plate upon which the stack stands, but is two or three inches below it, or low enough to allow the cupola to be turned over without striking the plate. This cupola may have

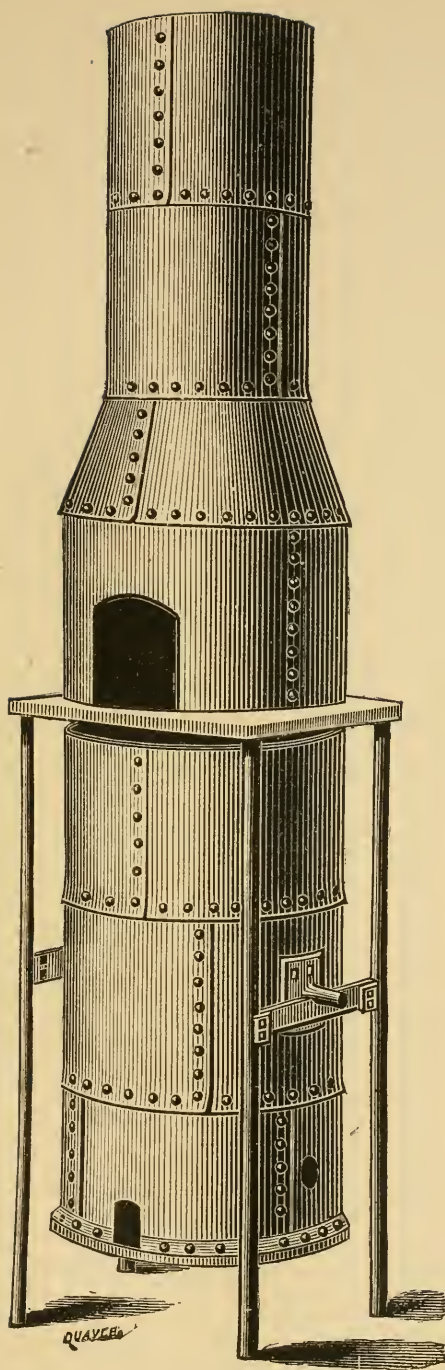


Fig. 16.

a drop bottom or a stationary bottom with a brick hearth. When the bottom is stationary, the refuse may be drawn out at the front, or the cupola may be turned upside down and dumped. When the cupola is only fifteen inches or less in diameter, the stationary bottom is the best; but when the cupola is over fifteen inches in diameter, the drop bottom is to be preferred. When the drop bottom is used for this cupola, it should be supported by a latch or cross-bar, and not by a prop, for the cupola may be rocked a little when charging the stock, and the prop will give way. The swivels or bearings should be bolted on to the cupola a little below the centre, so as to have the cupola as nearly balanced as possible when the iron bottom is on, so that the cupola will be easy to turn on the swivels. This cupola may be turned over by hand or by gear-wheels attached to the swivels. When the cupola is large, or where it is desirable to dump the refuse by turning the cupola upside down when hot, the gear wheels should be used. As only a small amount of iron is melted in this cupola at a time, a two-inch lining is heavy enough for it. When picking out and making up the cupola for a heat, it may be laid over on its side and picked out with a long bar to avoid going into it. When it is desirable to melt more iron than the cupola is capable of melting, it may be run until bunged up, and then turned over and dumped, and picked out with a long bar while hot, and then turned up and fresh stock put in and the heat continued. This style of cupola should not be made more than twenty inches in diameter and six or seven feet high, as it would be too heavy to handle when lined. The swivel cupola is a very handy and convenient little one for melting small quantities of iron, and for mixing irons to test their quality, and no large foundry should be without one. Most of our large foundrymen have no small cupolas in their foundries, and when introducing new brands of iron they have to test their

qualities in the large cupolas, and through an entire heat, and in this way whole heats of castings are often lost, which loss might have been avoided by having a small swivel cupola and testing the quality of the iron on a small scale, before introducing it into the large cupola or through the entire heat.

THE SAND BOTTOM.

Sand gathered from the gangway is generally used for the bottom; a little new sand is sometimes added to give it more strength. All new sand, sharp or fire-sand, should never be used for the bottom (especially in small cupolas), for it will bake in too hard and not drop easily. Some melters prefer to gather the old bottom out of the pit and add a little new sand to it, and put it in again. This makes a very good bottom, as the sand from the old bottom will contain small particles of cinder, which will make it open and porous and prevent it from baking in hard, and make it drop easily. The old bottom should always be put into a small cupola in preference to sand from the gangway; the sand bottom should be put in so as to be high around the outside and have a gradual slope towards the centre and front. Care must be taken to not give it too much slope, as it will throw the iron out with too much force when tapped; care must also be taken to not get the bottom too flat, or the iron will not run out and will chill on the bottom and make dull iron. The thickness of the sand bottom will vary from two to ten inches, according to the size of the cupola. If the sand bottom is too wet it will make the first iron hard; if it is not rammed even and packed solid around the edges, it may allow the iron to run out; if it is rammed too hard the molten iron will not lay upon it, but will boil and cut up the sand, and make a dirty iron, and it may cut through the sand and run out through the iron bottom.

FRONT OR BREAST.

The front should be put in with sand or loam that will not bake in too hard, and will not cut nor crumble when the iron strikes it. A little fire-clay is sometimes used in the bottom of the spout and around the tapping hole, to prevent the tapping hole from cutting out and getting too large. The front should not be more than one and a half inches thick at the tapping hole, or the iron will be liable to chill in the tapping hole between taps. When the lining of the cupola is very thick, the brick should be cut away around the front on the inside, so as not to have the sand front too thick. Some melters put in their front before the fire is lit; this answers very well when the cupola is large and the tuyeres are low down, but it will not do in a small cupola with high tuyeres. Coke melters build up a wall of coke in front of the fire and ram the sand against it; this makes a very good front. Some coal melters cut a piece of board the proper size, with a notch in the bottom of it, and set the board back against the hot coals, and ram the sand against the board; this makes a very nice front, for the board soon burns out and dries the front, and leaves it straight and even on the inside. Most melters ram the sand back against the hot coals, and pay no attention to the inside of the front; this should never be done, for the front will be rough and uneven on the inside, and will cut and crumble with the heat and iron. This way of putting in the front is often the cause of dirty iron and of slag running out at the tapping hole.

TWO FRONTS OR BREASTS.

In some of the large stove foundries in Troy and Albany, N. Y., two fronts are put in their large cupolas. They are both put in on one side of the cupola, about

ten or fifteen inches apart. This is done for safety. They are tapped turn-about, and it is claimed that the tapping hole can be kept in better order, and in case one tapping hole gets in a bad shape, it can be stopped up altogether and the other one used. I think that putting in two fronts in this way only makes more work for the cupola-tenders, and more expense for loam or sand, without gaining anything; for the tapping hole will never get in a bad shape if the front is put in right and is tapped right; and if it does get in a bad shape, it is an easy matter to stop the blast a few minutes and fix it or put in a new front. In the foundry of James L. Haven & Co., in Cincinnati, Ohio, two fronts are put in their large cupola, one on each side; this is done for convenience in carrying away the iron, and not for fear of the tapping hole giving out, or on account of fast melting.

THE SPOUT.

The spout may be made up with the same kind of sand or loam as the front or breast is put in with. It is a good idea to paint the spout with a little blacking mixed with water; this prevents the iron from sticking to the sides of the spout. The spout may be dried by the flame blowing out at the tapping hole before the iron comes down. If an iron plate is laid on top of the spout while the flame is blowing out, the heat will be more confined and the spout more thoroughly dried. Building a big wood fire on top of the spout to dry it, is an old-fogy idea, and the man that invented it died a long time ago.

STOPPING BODS.

Molding sand, mixed with a little clay-wash, makes a very good bod that is easily tapped out. When fire-clay, or other heavy clay, is used for bods, a little

blackening or sawdust should be mixed with it, so as to make it tap easily. The blackening or sawdust will soon burn out and leave the bod porous, and it can be easily cut away. The first bod for stopping in with should be sharp-pointed, so that it can be shoved well back in the hole, to prevent the iron chilling in the hole before the front has been thoroughly warmed up. After the front and bottom have been thoroughly warmed, the bod should be made round, so as not to shove it back into the hole too far, and to make it tap easily. Care should be taken to have the bod-clay thoroughly mixed, and not too wet nor dry. Tappers often lose their eyes or get badly burnt by the careless way in which they mix and handle their stopping bods.

STOPPING OR BOD STICKS.

The tapper should have at least three bod sticks—one good large one—always ready in case of accident. Bod sticks are generally made of all wood; but some prefer an iron rod, from six to twenty inches long, with a button on one end and a long wooden handle on the other. This makes a good bod stick, where a long spout is used; for the iron rod will not burn away, as the wood will do from the heat in the spout. A bod stick made in this way may be used for years.

TAPPING BARS.

The tapper should have at least three tapping bars; one a one-half inch, one a three-fourths inch, and one an inch in diameter. They should be long enough, so that the tapper can stand back from the cupola, and not be in danger of getting burnt every time he taps

out. The bars should be drawn down to a long square point, so that the bod can be cut away by turning the bar, and leave a nice, smooth, clean hole. If the tapping bar is round and blunt on the end, the bod will be shoved into the cupola, and the molten iron, running out, will force it back into the hole, and prevent the iron from running out freely.

LIGHTING THE FIRE.

Too much care cannot be taken in starting the fire in the cupola ; for the fire in the bottom of the cupola is the foundation upon which the iron is melted. The theory of starting the fire in any shape, and depending upon the blast to equalize it, is wrong. My experience is, a poor fire on the start makes poor iron all through the heat. The wood to light the coal or coke with should be cut in lengths of from ten to eighteen inches ; and two or three rows of wood should be set upon end around the sides of the cupola, so as to protect the dobbing and give the fire vent. The centre should be filled in with short wood, so arranged as to give the fire the best possible chance to burn. The wood, when all in, should be level and even on top. When the wood is cut short, and put in the cupola in this way, one-third less will be required, and the coal or coke will be lit more even, and better melting can be done than when the wood is put in long and uneven. Gas-house coke is sometimes used with wood for starting the fire when coal is used for melting ; this is done for economy. Less wood is required when the gas-house coke is used, and the coke is often cheaper than the wood. Some melters put their wood into the cupola in the regular cord-wood lengths, and throw it in in any shape. The coke or coal is put in, and will roll down through the

wood and lay on the bottom ; the fire is lit, and the wood is all burnt out, and the coke or coal is only lit in spots, and probably there will be a pile of coke or coal lay on the sand bottom under the tuyeres that is not lit at all until the iron is melted and runs through it. This careless way of starting the fire is often the cause of dull iron and slow melting.

CHARGING WITH COAL.

After the wood has been put into the cupola in the proper shape, the coal for the bed should all be put in before the fire is lit, except a few pieces to level up with after the wood is all consumed and the coal allowed to settle. After the wood has all burnt out and the bed has settled, the top of the bed, when all in, should not be more than twelve or fourteen inches above the top of the tuyeres. No regular time can be set for charging the iron, for the cupola will have a better draft on one day than another ; and care must be taken not to get the bed burnt too much before the iron is charged. When the wood is entirely consumed, and the bed has settled and burnt through, so that the fire can be seen on the top of the bed, it is time to charge the iron. A few plates or other light scraps should be put in on the coal, to prevent it from being broken up by throwing in the heavy iron, and to prevent it from settling down into the bed, as it will do if the coal used for melting is small. The pig-iron should be charged with the face or top of the pig down, and the ends out towards the lining, as it will melt better than if charged with the side of the pig flat up against the lining, with the coal only on one side of it ; it should be charged as compactly together as possible, so as to utilize all the heat from the coal, and not allow it to escape up the

stack. Each charge of iron should be level on top, and not high in the centre, as it will throw the coal and heat to the outside, and will cut the lining of the cupola more than if charged level; it should be charged in as large charges as the cupola will melt, so as to have a good bed of coal between the charges of iron, without using too much coal. The iron should be charged in the cupola from two to three hours before the blast is put on.

The bed should never be allowed to get white hot on top before the iron is charged. If the bed is burnt too much the iron will be dull through the first charge, and probably through the entire heat. If the bed is too high, or is not burnt enough, the iron will be a long time in coming down, and the cupola may melt slow through the entire heat. If too much coal is used between the charges of iron the cupola will melt irregularly. The iron should be down in five or ten minutes after the blast is on if the cupola has been charged right. The charging door should always be closed after the stock is all charged.

COAL MELTERS.

When melters, who have been accustomed to melting with coal, undertake to melt with coke in the same cupola, they should remember that their cupola has more draft than a regular coke cupola; that less wood is required to light coke than coal. Coke will burn up faster. The bed must be put in higher up. The iron should not be melted in as large charges. The coke should be charged by weight, and not by bulk; it will melt iron faster than coal, and care must be taken to keep it out of the tuyeres.

CHARGING WITH COKE.

Less wood is required for starting the fire when coke is used for melting than when coal is used. If the cupola has a good draft, all the coke for the bed should be put in on the wood before the fire is lit; but if it has a poor draft, only part of it should be put in before lighting the fire. When the wood has burnt out and the coke is red hot at the tuyeres, it is time to charge the iron. A coke bed should never be allowed to get red hot on top before the iron is charged. The top of the bed, when all in, should not be more than eighteen or twenty inches above the top of the tuyeres when the iron is charged. The iron should be charged from one to two hours before the blast is put on; it should not be melted in as large charges with coke as with coal. In other respects, the same directions should be followed as given in charging with coal, and the same results will be produced from improper charging.

COKE MELTERS.

When melters, who have been accustomed to melting with coke, undertake to melt with hard coal in the same cupola, they should remember that their cupola has not so much draft as a cupola built for melting with coal. More wood must be used to start the fire; and it must be lit earlier. The bed must not be so high. The iron must be charged in larger charges. The coal should be charged by weight, and not by bulk. Coal will melt iron slower than coke.

PIG-IRON.

All pig-iron has more or less sand on it, and has a hard, chilled scale under the sand, which resists the action of the heat upon the iron, and prevents its melting. If the pig is broken before it is charged, it exposes the clean iron in the ends of the pig to the heat, and it will be noticed that the pieces of pig dropped through, partially melted, have commenced to melt at the ends where the clean iron was exposed to the heat. Pieces of pig will sometimes be found where their ends have been melted out for an inch or more, and left the outside scale on the pig standing, which shows that this scale resists the action of the heat upon the iron; and the shorter the iron is broken, the more clean ends will be exposed to the heat, and the better it will melt, and less fuel will be required to melt it. A pig should be broken in at least three or four pieces before being charged. In charging the cupola the pig-iron should be thrown in with the face or top side of the pig down, as it has less scale on the top than on the sides, and will melt better. All these little points are taken advantage of by the practical and scientific melter.

PRESSURE OF BLAST.

The blast should be put on light at first; not more than one-half of the pressure should be put on for the first five or ten minutes. The pressure of blast used for melting iron in cupolas will vary from six to sixteen ounces, the best melting being done with from eight to ten ounces pressure with coke, and with from ten to fourteen ounces pressure with coal. The foundryman or melter should use his own judgment about the blast, and he should know by practical experience when he

has enough, too much or too little blast. Too much dependence should not be placed upon air-gauges, as they may show a great pressure of blast, and the tuyeres be too small to admit of volume enough of blast to do good melting. The air-gauge will invariably show more pressure of blast toward the last of the heat, when the tuyeres have become bunged up, than at the first of the heat, yet the cupola will have less blast. Too little blast will cause slow melting; too much blast will harden the iron and make it dull, unless too much fuel is used. See COMBUSTION AND HEAT.

DUMPING THE CUPOLA.

The blast should be taken off as soon as there is enough iron melted. It is better for the cupola to drop the bottom with a little unmelted iron in it than it is to melt every drop before dropping the bottom. Ten minutes blowing after the iron is all melted, will make the cupola harder to dump, and will injure the lining more than two hours melting would do when the cupola was full of stock. The melter should never throw iron into the cupola after the stock gets too low, or the iron is all melted. If a little more iron is charged in a small cupola than is wanted, it will make it easy to dump; the bottom should never be dropped when there is any molten iron in the cupola.

FIRE IN THE DUMP.

Some melters never put out the fire in the dump, but allow it to burn out. This should not be done, for there is a great deal of fuel dropped through the cupola, partly burnt, that may be used again in the cupola or

under the boiler; and by allowing it to burn up in the dump it does no good, but does harm in cementing the dump more solidly together and making it harder to shovel out.

THE DUMP.

The dump should be carefully picked over as it is taken out from under the cupola, and the large pieces of iron and fuel thrown out. If the old sand bottom is to be put in again, it should be riddled out of the dump and the cinder should be put in the mill and ground, and all the iron carefully picked out of it. If there is no mill, the cinder should all be broken up fine and riddled through a No. 2 riddle, so as to get all the iron. Some melters throw more iron away in the dump, every day, than would pay their wages. I have seen old men and women make a good living, at Pittsburg and other places, by gathering the iron out of the dumps from cupolas after they had been thrown out on the bank of the river, and selling it for one-fourth cent per pound.

PIG MOLD FOR OVER-IRON.

Stove molders always have more or less little dribs of iron left in their ladles, which they cannot pour into their work; and these little dribs will generally make the iron too dull to run their work if they are kept in the ladle until the next catch; so, to get rid of it, the molder will pour it down in the gangway, or at the back end of his floor, or most any place. In this way a great deal of iron is lost in course of time; or if it is not lost, it becomes mixed with sand and dirt, and will make a dirty iron when re-melted. To prevent this waste of iron, the foundryman should have a cast-iron

pig mold (as shown in fig. 17) set in the gangways at the head of each man's floor, so that the molder can pour all the little dribs of over-iron into it, and collect them in one pig. These molds are the best when made to hold about half a ladle of iron; they can then be easily turned over, and the iron turned out, and the mold re-filled, if necessary; or the molds may be made larger, and a few of them set around the cupola instead of in the gangways. These pig molds have been made



FIG. 17.

with a swivel on each end, and hung in a cast-iron frame, and are dumped by means of a crank, when full, and again re-filled; but this arrangement has generally been abandoned in favor of small molds in the gangways, and a few large ones around the cupola. Care should always be taken to have these molds dry and clean, and the molder should always be careful to pour the iron into them slow at first, and heat the mold gradually to prevent the iron from exploding.

COMBUSTION AND HEAT.

All ordinary processes of fermentation, decay and fire are produced by a union of oxygen with a substance, and are only different forms of combustion; they differ in the time employed in the operation. If oxygen unites rapidly, we call it fire; if slowly, decay. Yet the process and the products are the same in the combination of an atom of oxygen with an atom of carbon,—a certain amount of heat is produced. Hence, the house that decays in fifty years gives out as much

heat during that time as if it had been swept off by a fierce conflagration in as many minutes. If we supply our cupolas with oxygen rapidly, the combustion will be rapid and the heat intense. If we supply it slowly, the combustion will be slow and the heat mild. Hence, the use of a blast for our cupolas. In order to form a thorough combustion of fuel, every two atoms of oxygen must unite with one atom of carbon. If less than two atoms of oxygen are supplied to one atom of carbon, the combustion is not thorough. If more than two atoms of oxygen are supplied to one of carbon, it will not form a chemical combustion, but a mechanical destruction of the fuel. If the blast is too mild, we have a thorough combustion, but we do not have a rapid combustion, nor an intense heat; and more fuel and more time is required to make hot iron, but there will be little or no slag; there will be more ash, and the cinders in the cupola will be brittle and easy to pick out in a short heat; but if the cupola is kept in blast for a long time, the ash may become cemented together and form a tough cinder, and the cupola will be hard to pick out. If we have too much blast, or a too sharp and cutting blast, the oxygen cannot combine with the carbon of the fuel so rapidly, but it will overcome the carbon, and will make an intense heat; but the heat will be short-lived. The iron cannot take up the heat so rapidly, and more fuel is required to make hot iron; and there is not a chemical combustion of the fuel, but a mechanical destruction; for the oxygen of the blast combines with the carbon of the fuel so rapidly that the non-carbonic residue of the fuel is not consumed, but is converted into a slag.

Foundrymen will often notice that they have more slag on one day than another. This slag is generally caused by more blast on one day than another; and more blast may be supplied by running the fan or blower faster, or by charging the cupola so that it is

choked down, and the carbonic-acid gas cannot escape. Hence the cupola should be charged even, and the fan or blower run to suit the cupola. If we only supply the cupola with enough oxygen to form a thorough and rapid combustion, the heat will be intense, and will make little or no slag; for the non-carbonic residue of the fuel will be converted into an oxide or light cinder, and will be carried out at the top of the stack,—less fuel will be required to make hot iron, and it will be melted at a more even temperature, and make a better casting. I have often seen two cupolas made up in the same shape, and both melting the same irons; one of them would make a great deal of slag, and be hard to pick out, while the other made little or none, and was easy to pick out. This was because the cupola that made the slag had too much blast.

Chemists tell us that, in order to produce a perfect combustion, we must have two atoms of oxygen to one atom of carbon; but the question is, how are we to know when we have two atoms of oxygen or one atom of carbon, or how are we to know when we have too much or too little blast? This is a question that can only be answered by practical experience, as no rule can be given that will hold good in all cupolas. Yet I might make some suggestions that would assist the foundryman in regulating his blast. In visiting different foundries through the country, I have found that scarcely any two cupolas are charged exactly alike, although they may be exactly the same size, and, to all appearance, the same. Yet the stacks may not be so high, or one cupola may be set along side of a high building or down in a hollow, so that it will have little or no draft; and if charged exactly the same as a cupola that has a good draft, the result would be that we would not have a thorough combustion, and probably we would have a dull iron. Still this cupola with the poor draft may be charged so as to do good melting; but it cannot be

made to do as fast melting as a cupola with a good draft. Thus we may, by varying our charges of fuel and iron, produce a thorough combustion, and do good melting in any cupola. I should recommend fast melting in cupolas, a good strong volume of blast, and a varying of the charges of fuel and iron to suit the blast and cupola. I should recommend high stacks on cupolas, and a good draft. I should recommend charging the iron compactly together, so as to utilize all the heat from the fuel; but the iron should not be packed so close as to form a complete damper over the fuel, and not admit of the escape of the carbonic-acid gas which is formed by the combustion of the fuel.

THE MELTING POINT.

The theory that iron in a cupola is melted all up through the stock is wrong, for every cupola has a certain point at which the iron is melted, and there is not a pound of iron melted in any cupola until it comes down to the melting point. The melting point in a cupola is generally from six to eighteen inches above the tuyeres, but it may be raised or lowered a little by increasing or diminishing the amount of fuel in the bed; but if we get the bed too high it throws the melting point too high, and the result will be slow melting. If we get the bed too low, it will allow the iron to get below the melting point, and the result will be dull iron; and in order to do good melting in any cupola, it is very essential that the melter should know the melting point of his particular cupola. The melting point of a cupola is the point at which the most intense heat is created by the action of the blast upon the fuel. This intense heat at the melting point will cut the lining more than at any other place in the cupola, and the

lining will generally be found to be cut out more just above the tuyeres than at any other point, which indicates the melting point of the cupola. If the tuyeres are put in so as to distribute the blast evenly through the stock, and the charges of iron and fuel are put in evenly, and every charge leveled up properly, the heat will be even all through the cupola, and the lining will be cut out in a regular belt at the melting point all around the cupola. On the other hand, if the tuyeres are not put in so as to distribute the blast evenly through the stock, or the charges of iron and fuel are not put in even and level, or if the fire is all on one side of the cupola, the heat will not be even through the cupola, and the lining will not be cut out in a regular belt at the melting point, but will be cut full of holes, which shows that the cupola is not melting all around, but is only melting in spots. By this irregular charging and melting in spots, the cupola may be reduced to half its melting capacity, which accounts for a cupola melting fast on one day and slow on another day. As before intimated, the melting point in a cupola is the point at which the most intense heat is created by the action of the blast upon the fuel. When the blast enters the cupola it is cold, and as it passes through the heated fuel it becomes hot, and as it becomes hot it creates heat by combination with the fuel, and makes an intense heat. If we have a very strong blast it will travel fast and will pass through the fuel rapidly, and it will have to pass through more fuel before it becomes heated sufficiently to make an intense heat by combination with the fuel. On the other hand, if we have a mild blast, the blast will pass through the heated fuel slowly, and is more heated, so that it does not have to pass through so much fuel before it becomes sufficiently heated to make an intense heat by combination with the fuel; so that when we have a strong blast the melting point of a cupola is higher than when we have a mild or weak

blast; and the bed has to be put in higher in a cupola with a high melting point than in a cupola with a low melting point, which accounts for one cupola requiring more fuel in the bed than another cupola does. When the cupola is in blast, the bed or fuel in the bottom of the cupola is constantly burning up, and the unmelted iron will get down below the melting point. To prevent this, the melter has recourse to charges of fuel between the charges of iron, and as the charges of iron are melted and drawn out at the tap hole, the charges of fuel come down and replenish the bed and again raise the melting point; the next charge of iron comes down and is melted and drawn out; the bed is reduced and is again replenished by the next charge of fuel, and so on through the whole heat. If we supply too much or too little fuel between the charges of iron, the melting point will be raised too high or reduced too low, or in other words, if we have a melting point of ten or twelve inches in height in our cupola, and we supply twenty or twenty-five inches of fuel, this extra fuel must all be burnt up before the iron can come down to the melting point; and we will not have a continuous melting, but will have a delay between each charge of iron. If, on the other hand, we have only five or six inches of fuel between the charges of iron, when we should have ten or twelve inches, this small amount will not more than half replenish the bed, and the unmelted iron will get down too low and will not make hot iron, and the iron may not be melted at all; and in order to do either fast or economical melting, we must not use either too much or too little fuel, and we must have the fuel distributed so as to suit the particular cupola in which it is used; for, as before explained, there are scarcely two cupolas that will melt exactly alike on account of the melting point being higher or lower, which is caused by a stronger or weaker blast, or by more or less draft; and in order to do good melting,

the melter should not charge his cupola just the same as some other cupola of the same size is charged because that cupola does good melting charged in that way ; but he should vary the height of the bed and the amount of fuel between the charges of iron, and the amount of iron on the bed and on each charge of fuel, until he finds the exact proportions that will do the best melting in that particular cupola.

Melters, in changing from one cupola to another, will generally have trouble in making hot iron, and they will often make a complete failure of melting in a strange cupola. This is simply because they undertake to charge that cupola the same as some other cupola that they have been melting in, and they never pay any attention to the draft, blast, or the melting point of the cupola, which is the cause of their failure in melting in a strange cupola. When a melter takes charge of a strange cupola, his first object should be to study the draft of the cupola, the nature of the blast, and to ascertain the melting point of the cupola. He can generally tell where the melting point is by noticing where the lining is cut out the most, and he can tell whether the cupola is melting evenly, or is only melting in spots, by noticing whether the lining is cut out in a regular belt all around the cupola, or is only cut out in holes, as before explained. He can tell whether the bed is too high or too low by noticing how the cupola melts. He can tell whether he is using too much fuel between the charges of iron, or if he is putting in the charges of iron too heavy, by noticing whether the cupola melts regularly or not, and by noticing if it makes regular iron ; for if the iron is very hot in one part of the heat and dull in another part, it is a sure indication that the fuel is not properly distributed through the iron, and it should be remedied by increasing or diminishing the weight of the charges of fuel or iron.

In melting with coke, the melter cannot put in his

iron in as large charges as he can with coal, because the coke is more bulky than coal, and he has more bulk in the same weight, and if he puts the same weight of coke between the charges of iron as he does of coal, the bulk of the coke will raise the iron above the melting point, and the iron cannot be melted until part of the coke is burnt up so as to allow the iron to come down to the melting point, and the result is that he does not have a continuous melting, but he has a delay between each charge of iron, and the iron will probably be dull in the latter part of each charge; but the melter can do equally as regular melting, and can do faster melting with coke than he can with coal, by putting in the coke and iron in smaller charges, and more of them, which proves conclusively that good melting can be done with almost any fuel and in any cupola, if the melter understands his business; but he may not be able to do as economical melting in a poor cupola as he can in a good one.

BLAST MACHINES.

All the old style blast machines, such as the leather bellows, the trompe or water blast, the chain blast, and the cogniardelle or water-cylinder blast, have gone out of use in the foundries in this country, and have generally been replaced by the cylinder or piston blowers, and these last are rapidly giving way to the more modern machines, which are cheaper and require less power to run them. The principal improved blast machines that are in use in foundries at the present time are, the McKenzie blower, the Root blower, the Baker blower, the Clark fan, and the Sturtevant fan. The McKenzie blower is a pressure blower; it is manufactured in the State of New Jersey, and is the oldest rotary pressure blower in use. It is in general use all over the country,

and gives a good blast. The Root blower is also a pressure blower; it is manufactured in the State of Indiana, and is in general use through the West. The Baker blower is also a pressure blower; it is manufactured in Philadelphia, and is in use in a great many foundries in Philadelphia and New York. The Sturtevant fan is not a pressure blower; it is manufactured in Boston, and is in general use all over this country. The Clark fan, like the Sturtevant fan, is not a pressure blower; it is manufactured in the State of New Jersey, and is in general use all over this country. All the above blowers and fans are rotary blowers or fans.

I have melted iron with all these blowers and fans, and have been able to do as fast and as economical melting with the one as the other. Any of them will make a good blast for a cupola, and the only advantage that any of them have over the other is in the power required to run them. The blowers are all sold at about the same price, but there is considerable difference in the price of the fans; the Clark fan is sold a great deal the cheapest.

There should be some little difference in charging a cupola where a fan or blower is used, for the fan blast is not a forced blast, and the stock can be charged in a cupola so compactly together as to choke it down and shut off the blast; and in charging a cupola the iron should not be packed in too solidly, nor should it be packed too open, or the heat will escape up the stack and more fuel will be required to make hot iron, but we must keep between the two extremes. Even if a forced blast is used, the stock should not be packed too solidly, for the carbonic acid gas formed by the combustion of the fuel cannot escape and will injure the iron.

The Disston Centennial Pressure Blower is a new blower that has lately been invented, and is manufactured in Philadelphia. I have not seen any of these blowers in use in foundries, but they are said to be a first class blower.

THE ATMOSPHERE.

It is often claimed by foundrymen and melters that the changes in the atmosphere affect the working of the cupola and the melting of iron, and that less fuel is required to melt iron on a damp or cold day than is required to melt the same iron on a warm, clear day. I have watched these points closely, and have observed that iron melted on a cold or dark day seems hotter than iron melted on a warm, clear day. This is because there is more contrast between the molten iron and its surroundings. If we light a candle in daylight the flame will seem to make less light than it would at night or in the dark, yet there is the same amount of flame and the same amount of gases consumed. A bar of iron that would look black-hot in daylight, would look red-hot in the dark, yet it will not burn you any worse in the dark than it would in the light. If we heat a bar of iron in the forge and draw it out of the fire suddenly, it will look hotter than when it lay in the fire, because we see more contrast between the hot iron and the cold air than we did between the hot iron and the hot coals; yet there is often a real difference between the working of the cupola on one day than on another.

Some melters make a practice of lighting their fire in the cupola at a certain time, and charging the iron at a certain time every day. On a bright, clear day the the cupola will draw better than it will on a damp, rainy day, and the bed will be burnt more on a clear day, and will probably make a duller iron than it would on a damp, rainy day. When the cupola had little or no draft, and the bed was not so much burnt up, the melter will generally attribute the difference in the iron, on a rainy day and a clear day, to the effect of the atmosphere on the cupola and iron, when really the difference

is caused by the way in which the bed is burnt. This may all be overcome by watching the wind and weather, and lighting the fire a little sooner or later, to suit the draft of the cupola. From what I have observed, I do not think that the changes in the atmosphere make any difference in the melting of iron in a cupola, except as explained above.

FLUXES AND FLUXING.

These terms are respectively applied to substances which impart igneous fluidity when heated with other substances, and to the manner of using them. The alchemists tried to discover a fluid which should have the property of dissolving all things wherewith it might come in contact. They neglected to reflect that a necessity would arise for a vessel to keep it in. Practice demonstrated the fact, that coal or coke-smelted iron was inferior to charcoal-smelted iron. Analysis of coal or coke-smelted iron demonstrates the existence of both sulphur and phosphorus, and that the amount of deterioration in the iron was in direct proportion to the quantity of these elements which the fuel contained. With a view of getting rid of these impurities, and making a coal or coke-smelted iron equal to a charcoal-smelted iron, the manufacturer has had recourse to fluxes and fluxing in the blast furnace, and for the purpose of imparting igneous fluidity, the blast furnacemen have used lime, or the carbonate of lime, as a flux, and they have assisted in improving the quality of the iron and in carrying off the non-metallic residue of the ores in the shape of cinder or slag; and foundrymen, thinking that what is good as a flux in a blast furnace must be good as a flux in a cupola, have adopted the use of lime or the carbonate of lime as a flux in their foundry cupolas, but they have neglected to reflect that there is a

great difference between a blast furnace and its workings, and a cupola and its workings. The blast furnace is stocked with ores that have a non-metallic residue which must be carried off; the foundry cupola is stocked with pig-iron, which has little or no non-metallic residue; the blast furnace is kept continually in blast, and the stock is subjected to from twenty-four to forty-eight hours heat in the furnace before it is tapped out in the shape of iron and cinder; the foundry cupola is only in blast for a few hours, and the stock is only subjected to the heat of the cupola for a short time; and whereas lime or the carbonate of lime does improve iron in a blast furnace where it is subjected to a long, continuous heat, they will not affect the iron in a foundry cupola where the iron is only subjected to their influence for a few minutes. And in order to flux and improve iron in a cupola, the foundryman must have recourse to a more powerful flux than lime or the carbonate of lime. With a view of discovering a flux that would affect iron in a foundry cupola, I have spent a great deal of time and money in experimenting on fluxes and fluxing, and I now have the best chemical flux ever offered to the public for use in foundry cupolas. With the aid of my flux almost any iron can be run into first-class work.

L I M E S T O N E F L U X .

Limestone has been used as a flux in the melting of iron, for centuries, and is used more or less at the present time. Most of foundrymen who use limestone consider a small riddle-full, finely broken up, sufficient for a heat of three or four tons of iron, but in some parts of the country, and in Cincinnati, Ohio, some of the foundrymen charge large quantities of limestone into their

cupolas, and tap slag the same as a blast furnace. This they claim purifies the iron. I have seen limestone used at the rate of one hundred and fifty pounds to the ton of iron (at Zanesville, Ohio) in a straight cupola forty inches in diameter, and slag tapped.

I do not consider that the use of limestone in a cupola, either in large or small quantities, is any advantage either in melting or cleaning the iron; in fact I have found it a great disadvantage by careful tests made with and without it. Careful tests were made at the foundry of James Marshall & Co., Pittsburg, Pa., in 1874:

35,150 pounds of iron were charged in the Truesdale patent cupola; 32,144 pounds obtained; 3,006 pounds lost in melting, with a large percentage of limestone and slag tapped.

33,000 pounds of iron were charged in their common straight cupola; 31,235 pounds obtained; 1,765 pounds lost in melting, without any limestone or other flux.

The loss with the limestone was 3,006 pounds, while the loss without it was 1,765 pounds, showing a difference in favor of no limestone of 1,241 pounds, or a little over three per cent.

When limestone is used in a cupola in small quantities, it makes a heavy, tough slag that will run out at the tapping hole and bung up the spout and ladles. I claim that limestone should never be used in a cupola, either in large or small quantities, for the following reasons:

1st. It takes coal or coke to melt it.

2d. It don't do the iron or the cupola any good after it is melted.

3d. It makes the slag in the cupola tougher and harder to pick out, especially if the limestone is poor.

4th. It makes the wastage of iron greater.

OYSTER-SHELL FLUX.

Oyster shells are, like limestone, extensively used as a flux in melting iron in cupolas, but they are worse than limestone. It is a well-known fact that shells contain a large percentage of phosphorus, and in using them as a flux in the cupola, the phosphorus is taken up by the iron and is by it made a cold-short, harder and weaker iron. The use of shells in large quantities makes it necessary to use a much higher grade of iron to produce an equally good casting.

FLORA-SPAR FLUX.

Flora-spar has been used as a flux in melting iron in cupolas, and it makes a very good flux if the flora-spar is pure; but when it is poor it is very hard on the lining of the cupola, and for that reason it has generally been abandoned as a flux in cupolas.

MARBLE-SPALLS FLUX.

Marble-spalls are sometimes used as a flux in cupolas; they make a very good flux, and I should recommend using them in small quantities.

PATENT FLUXES.

Several patent fluxes have been invented, and introduced and used with more or less success. MY PATENT FLUX IS THE BEST.

CHARCOAL FLUX.

Sometimes charcoal is used as a flux. It is put into the cupola in small quantities with the iron and fuel, and is very good to give life to the iron; but it is dangerous on account of fire, as it is easily blown out of the cupola, and the sparks may set fire to the foundry or other buildings.

POTATO FLUX.

A raw potato is sometimes stuck on the end of a tapping bar and put down to the bottom of a large ladle of iron; this makes the iron boil and throws the dirt to the top of the iron, when it can be skimmed off.

CLEAN IRON AND SOUND
CASTINGS.

The best way to clean iron and make good, clean and sound castings, is to melt the iron good and hot, and pour it hot and fast. The quicker iron can be put into a mold the better. If the sand will not stand hot iron it is not good molding sand, and should not be used for molding. The most of the dirt and dross in castings is caused by the molder allowing his iron to stand in the ladle until it is nearly set, so as to allow the dirt to rise to the top of the iron and be skimmed off before the iron is poured; they will then dribble it into the mold and the casting will be full of dirt and dross, when, if the iron was poured hot and fast, it would have life enough to carry any dirt that might be in the mold up and out of the riser, and the dross in the iron would have a chance to rise before the iron sets.

POLLING IRON.

Some foundrymen, in order to mix the different brands of iron properly in the reverberatory furnace, poll the iron. This is done by taking a long pole of hickory, or some other strong wood, and running the end of the pole into the molten iron and stirring the iron with it. The wood poll is better for mixing the iron with than an iron bar is, for the wood causes the iron to boil around it; and we not only stir up the iron, but we boil it up and cause it to mix more thoroughly than if we only stirred it up with an iron bar. Iron is sometimes polled in a large ladle after it has been melted in a cupola, and it is said to improve the quality of the castings. Iron may be thoroughly mixed in a ladle by putting a raw potato on to the end of a tapping bar and stirring the molten iron with it. A ball of clay, or anything that will cause the iron to boil gently, is equally as good as a potato. I should recommend polling iron in all cases where the iron is tapped in large ladles, and it is desirable to make a first-class casting.

S L A G .

Some melters are always troubled with slag running out at the tapping hole with the iron and bunging up the spout of the cupola. This slag may be caused by limestone or oyster shells used as a flux, or by the sand on the pig-iron, or rust on the scrap, or by fine coal and sand shoveled into the cupola with the fuel or iron, or by slate in the coal or coke. The careless way in which some melters put in their sand bottom and the front or breast, will cause slag to run out at the tapping hole; but one of the principal causes of slag is the careless

way in which sand or dirt is shoveled into the cupola. Some melters never sweep or clean up the floor of the scaffold, but shovel all the dirt into the cupola with the fine iron or scrap. This dirt is all melted and converted into slag. Another cause of slag is the unthorough combustion of the fuel, or too much blast. This trouble may be overcome by reducing the blast or increasing the fuel. See COMBUSTION AND HEAT.

DAUBING FOR LADLES.

Molding sand mixed with a little clay-wash or molasses-water makes a good daubing for hand ladles or other small ladles; loam, horse-manure and a little sharp or fire sand make a good daubing for any sized ladle. Salt should never be used in daubing for ladles, for it will make them harder to dry, and will draw the dampness after they are dry if left standing for a while, and will cause the iron to boil in the ladle. Fire clay or any other heavy clay should never be used for daubing ladles (especially small ones), as it is almost impossible to get them dry in the oven so that the iron will not boil in them. The first catch ladles should be daubed as lightly and evenly as possible, so as to have them dry evenly and quickly, and be light to handle without any danger of their cutting through and running out. Large ladles that have to be daubed heavily should be perforated with small holes around the bottom so as to allow the gas to escape when the daubing is not thoroughly dry without boiling the iron. If the daubing is painted with a little blacking mixed with water, the iron will not stick to it.

LADLE REST.



FIG. 18.

Fig. 18 represents a ladle rest for resting the double end of the shank upon while the moulder is pouring the iron. This rest is made by taking a piece of wood two or two and a half inches square and three feet long, and driving spikes into it four or five inches apart, and allowing the spikes to project out three or more inches from the wood. The skimmer-boy carries this rest around with him and sets it down at any place where the molder may wish to pour, so that the molder may rest the shank upon the spikes. By this arrangement the ladle may be held up with ease, and held more steadily than a man could hold it by hand.

PERCENTAGE OF FUEL.

There is a great difference of opinion in regard to the amount of fuel required to melt a ton of iron, and there is a great difference in the amount actually used, as will be seen by reference to test heats made in different foundries in different parts of the country. Some foundrymen will claim that they are melting from ten to twelve pounds of iron to one pound of fuel, and they will get out their books and show you the exact amount of fuel used and iron melted, which will figure out very well; but in most of these cases the old melter has neglected to weigh the few little pieces of coal or coke that he has put in to fill up the holes, and these little pieces

sometimes amount to considerable. Other foundrymen will claim to be melting as high as fifteen or eighteen pounds of iron to one of fuel, but if you question them closely, you will generally find that the bed has not been counted in, and they are only figuring on the fuel used between the charges of iron.

I have found that the percentage of fuel actually required to melt a ton of iron will vary according to the quality of the fuel used, the construction of the cupola, the pressure of the blast, the way in which the iron is charged, the way in which the bed is burnt, and the amount of iron melted. A larger percentage of fuel is required to run off a small heat than would be required for a large heat in the same cupola. The best melting I have ever done, or ever seen done in a cupola, is seven pounds of iron to one pound of coal, and eight pounds of iron to one pound of Connellsville coke, and four pounds of iron to one pound of gas-house coke made from Pittsburg coal. I have found the average melting in foundries that I have visited, to be about four pounds of iron to one of coal, and about five pounds of iron to one of Connellsville coke, and about three pounds of iron to one of gas-house coke. Too much fuel is as bad as too little, and the amount actually required can only be ascertained by test, as no rule can be given that would hold good in all cupolas. The following heats that have been melted in different cupolas show the percentage of fuel used and the mode of charging. Most all of these heats were made in large foundries, where the stock is all weighed and melting is done systematically; and they represent a better average melting than is actually done through the country; but they show no better average melting than is actually done in the foundries where these heats were made:

Melting and mixing done at a large Stove Foundry in Albany, N. Y., July 29, 1876, in a straight cupola, with large coal all through the heat; fire lit at 12 M.; iron charged at 1 P. M.; blast on at 3 P. M.; bottom dropped at 5 P. M.; cupola 60 inches in diameter; five oval-shaped tuyeres $7\frac{1}{2}$ by $3\frac{1}{2}$ inches; tuyeres 4 inches above the sand bottom; on the back side; cylinder blast used.

COAL.	Pounds.	Sprews.	Crane, No. 1.	Allentown, No. 1.	Hudson, No. 1.	Allentown, No. 2.	Hudson, No. 2.	Drafts.	Lbs.
Bed	1800	400	168	164	168	100	100	1100	{ 1st charge, 4400 lbs.
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
1st charge ...	350	400	168	164	168	100	100	1100	{ 2d charge, 4400 lbs.
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
2d charge ...	350	400	168	164	168	100	100	1100	{ 3d charge, 4400 lbs.
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
3d charge ...	350	400	168	164	168	100	100	1100	{ 4th charge, 4400 lbs.
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
4th charge ..	350	400	168	164	168	100	100	1100	{ 5th charge, 4400 lbs.
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
		400	168	164	168	100	100	1100	
Total....	3280	8000	3360	3280	3360	2000	2000	22000	{ Gr'nd total 22000 lbs.

In this heat the chunks and scraps were counted as sprews.

Melting and mixing done at one of the leading Stove Foundries of Albany, N. Y., September 28, 1876, in a straight cupola about 70 inches in diameter, with cylinder blast; large coal was used all through the heat; fire was lit at 11.30 A. M.; iron charged at 12.15 P. M.; blast put on at 2.30 P. M.; bottom dropped at 5 30 P. M.

COAL.	Pounds.	Scrap.	Sprows.	Crane, No. 2.	Hudson, No. 2.	Po'keepsie, No. 2.	Chunks.	Total.	Lb .
Bed	1900	500	500	400	400	400	300	2500	} 1st charge, 5000 lbs.
1st charge...	350	200	500	500	500	500	300	2500	
		300	500	400	400	300	100	2000	} 2d charge, 4000 lbs.
2d charge....	400	300	500	400	400	400	300	2000	
		300	500	400	400	300	100	2000	} 3d charge, 4000 lbs.
3d charge....	400	300	500	400	400	400	...	2000	
		300	500	400	400	400	...	2000	} 4th charge, 4000 lbs.
4th charge...	400	300	500	400	400	400	...	2000	
		200	400	300	300	300	100	1600	} 5th charge, 3600 lbs.
5th charge...	400	300	500	400	400	400	...	2000	
		200	400	300	300	300	...	1500	} 6th charge, 3500 lbs.
6th charge...	400	300	500	400	400	400	...	2000	
		200	400	300	300	300	...	1500	} 7th charge, 3500 lbs.
7th charge...	400	300	500	400	400	400	...	2000	
		200	400	300	300	300	...	1500	} 8th charge, 3500 lbs.
Total	4650	4200	7600	6100	6100	5900	1200	31100	
									Gr'nd total 31100 lbs.

My flux was used in this heat.

Melting done at one of the largest Stove Foundries, in Albany, N Y., in 1876, in straight cupola, six feet in diameter in the shell, and lined with six inch brick; cupola five feet in the clear, six oval shaped tuyeres, four by twelve inches; Sturtevant fan blast:

	Lbs.		Lbs.
Coal in the bed	2,200	Iron on the bed.....	7,200
First charge of coal....	400		
Split of coal	100	Second charge of iron .	7,200
Second charge of coal..	400		
Split of coal.....	250	Third charge of iron..	7,200
Third charge of coal ...	400		
Split of coal.....	250	Fourth charge of iron .	7,200
Fourth charge of coal..	400		
Split of coal	350	Fifth charge of iron...	7,200
Total coal used	4,750	Total iron melted ...	36,000

In this heat the iron was put into the cupola in charges of 7,200 pounds, and in the middle of each

charge of iron a small charge of coal was put in; this is designated a split, when really it is only putting in the iron in charges of 3,600 pounds with one large charge of coal, and the next one small.

Melting done at the Car Works, at Berwick, Pennsylvania, March 25, 1876:

	Lbs.		Lbs.
Coal in the bed	1,900	Iron on the bed.	4,350
Coal in first charge....	500	Iron in first charge....	4,350
Coal in second charge .	600	Iron in second charge .	4,350
Coal in third charge... 700		Iron in third charge... 4,350	
Total coal used	3,700	Total iron melted....	17,400

The cupola was an oval-shaped cupola, called a fifteen ton cupola, with round tuyeres three and a half inches in diameter; the coal used was soft anthracite, from the Wilkesbarre region, and in order to keep up the bed, the charges of coal had to be increased toward the last of the heat; the iron melted was a mixture of cold blast iron and steel rails, for car wheels.

Melting and mixing, done at one of the leading Stove Foundries of Albany, N.Y., on September 28, 1876, in a straight cupola, about 50 inches in diameter, with cylinder blast; large coal was used in the bed, small coal between the charges; fire lit at 12 M.; iron charged at 1 P. M.; blast put on at 2.45 P. M., and heat melted in about two and a half hours:

COAL—Lbs.	Scrap.	Sprows.	Jagger, No. 2.	Hudson, No. 2.	Chunks.	Drafts.	Lbs.
Bed..... 1,500	300	500	500	500	200	2,000	} 1st charge, 4,000
	300	500	500	500	200	2,000	
1st charge, 350	300	500	600	600	.....	2,000	} 2d charge, 4,000
	300	500	600	600	.....	2,000	
2d charge, 350	300	500	600	600	.....	2,000	} 3d charge, 4,000
	300	500	600	600	.....	2,000	
3d charge, 350	200	500	600	700	.....	2,000	} 4th charge, 4,000
	200	500	700	600	.....	2,000	
4th charge 250	200	400	600	600	.....	1,800	} 5th charge, 2,100
	100	200	.....	.....	.....	300	
Total ... 2,800	2,500	4,600	5,300	5,300	400	18,100	} Gr'd total, 18,000

My flux was used in this heat.

Melting done at one of the Troy, N. Y., Stove Foundries, in 1876, in a straight cupola, six feet four inches in diameter in the shell, and lined with seven inch brick ; cupola five feet two inches in the clear ; six oval shaped tuyeres, three and a half by twelve inches, Sturtevant fan blast :

	Lbs.		Lbs.
Coal in the bed	2,500	Iron on the bed	8,000
First charge of coal ...	550	Second charge of iron .	6,000
Second charge of coal .	550	Third charge of iron...	6,000
Third charge of coal...	200	Fourth charge of iron .	2,500
Total coal used		Total iron melted....	
	3,700		22,000

In this heat the iron was charged in twenty hundred pounds drafts, thirteen hundred pig-iron, and seven hundred sprews and scrap ; fire was lit at 12 M., commenced charging at 12.30 P. M., blast on at 2.30 P. M., bottom dropped at about 4.30 P. M., pressure of blast thirteen ounces.

Melting and mixing, done at one of the Peekskill, N. Y., Stove Works, July 8, 1876, in a No. 4 McKenzie cupola, with a Sturtevant fan ; large coal used all through the heat ; fire lit at 11.40 A. M., iron charged at 12.30 P. M., blast on at 2.30 P. M., tuyeres six inches above sand bottom :

COAL—Lbs.	Plate.	Thomas, No. 1.	Crane, No 1.	Peekskill, No. 2.	Sprews.	Chunks.	Drafts.	Lbs.
Bed	1,200	300	400	300	500	400	100	2,000
			200	400	600	600	200	2,000
1st charge, 300	300	200	200	200	500	300	.....	1,500
		200	300	300	500	400	100	1,500
2d charge, 300	300	200	200	200	500	300	.....	1,500
		300	200	200	500	400	100	1,500
Total ...	1,800	900	1,500	1,600	3,100	2,400	500	10,000
								Grand tot. 10,000

My flux was used in this heat.

Melting and mixing, done at a Stove Foundry, Green Island, N. Y., October 21, 1876, in a round cupola, 48 inches in diameter at the charging door, and about 35 inches in diameter at the tuyers ; four tuyeres, 18 by 2 inches, were used ; large coal was used for the bed, small coal between charges ; fire lit at 12 M., iron charged at 12.45 P. M., blast on at 2.30 P. M., bottom dropped at 4.30 P. M. ; tuyers four inches from sand bottom on back side :

COAL USED.	Coal.	Plate.	Allentown, No. 2.	Hudson, No. 2.	Sprews.	Total.	Lbs.
In the bed..	1,200	300	500	400	300	1,500	} 1st charge, 3,000
1st charge..	500	100	600	600	300	1,500	
2d charge ..	400	100	600	600	300	1,500	} 2d charge, 3,000
3d charge ..	400	100	600	600	300	1,500	
			600	600	300	1,500	} 3d charge, 3,000
			600	500	300	1,500	
			600	600	300	1,500	} 4th charge, 3,000
Total coal,	2,500	600	4,600	4,400	2,400	12,000	} Total iron, 12,000

My flux was used in this heat.

Melting done at a Foundry in Poughkeepsie, N. Y., July 18, 1876, in a No. 4 McKenzie cupola ; coal used was small-sized hard coal, what is known as grate or steamboat coal. The fire was lit at 12.30 P. M. ; iron charged at 12.50 P. M. ; blast on at 2.30 P. M., and iron was down in 25 or 30 minutes ; Sturtevant fan blast was used.

	Lbs.		Lbs.
Coal used in the bed...	900	First charge of iron...	4,200
First charge of coal ...	300	Second charge of iron.	3,000
Second charge of coal..	300	Third charge of iron ..	3,000
Third charge of coal ..	150	Fourth charge of iron .	1,200
Total coal used	1,650	Total iron melted	11,400

This heat was melted in the same sized McKenzie cupola as the one used at the stove works at Peekskill, N. Y., and in this heat, as will be seen, there was almost one pound more of iron melted to the pound of

coal than was melted at Peekskill, and this iron was hotter and more even. This saving of coal and more even iron was caused by the small coal being used in place of large coal. When at Poughkeepsie, I suggested to the foreman of the foundry that he might obtain better results by lighting his fire sooner, and allowing it to get burnt up more before the iron was charged. He followed my suggestion and lit the fire an hour earlier, and charged the iron earlier and put on the blast at the same time. The result was, that the iron was down in five or ten minutes after the blast was put on, and one hundred pounds less coal were required for the bed.

Melting done at a Stove Works in Baltimore, Md., in a straight cupola 60 inches in diameter. The fuel used was Lehigh Valley coal and Connellsville coke.

	Lbs.		Lbs.
Coal in the bed	1,800	Iron on the bed.....	5,000
First charge of coke...	200	First charge of iron...	2,000
Second charge of coke.	200	Second charge of iron..	2,000
Third charge of coke ..	200	Third charge of iron...	2,000
Fourth charge of coke .	200	Fourth charge of iron..	2,000
Fifth charge of coke...	175	Fifth charge of iron....	2,000
Sixth charge of coke...	175	Sixth charge of iron....	1,500
Seventh charge of coke,	175	Seventh charge of iron .	1,500
Eighth charge of coke .	175	Eighth charge of iron..	1,500
Ninth charge of coke ..	150	Ninth charge of iron...	1,500
Tenth charge of coke ..	150	Tenth charge of iron...	1,500
Eleventh charge of coke	150	Eleventh charge of iron,	1,500
Twelfth charge of coke,	100	Twelfth charge of iron..	1,500
Total coal and coke used	3,850	Total iron melted	25,500

This way of making the bed of coal and the charges of coke has been adopted in some parts of the country, and seems to work very well.

Melting done in Cincinnati, Ohio, in a straight cupola, forty inches in diameter, with four round tuyeres three inches above the sand bottom, with Connellsville coke and a Root blower.

COKE USED.	Coke.	Scioto.	H. rock.	Sprows.	Scrap.	Total.
First charge.....	400	300	300	200	200	1000
Second “	50	200	200	100	200	700
Third “	50	200	200	100	200	700
Fourth “	50	200	200	100	200	700
Fifth “	50	200	200	100	200	700
Sixth “	50	200	200	...	300	700
Seventh “	50	200	200	...	300	700
Total iron melted ...	700	1500	1500	600	1600	5200

Melting done at Louisville, Ky., in a straight cupola thirty inches in diameter with two round tuyeres six inches above the sand bottom, with old style fan and gas-house coke. The iron was used for house-work, and had to be hot.

Coke used.	Coke.	Scioto.	Worley.	Scrap.	Sprows.	Lbs.
In the bed.....	500	200	200	300	100	800 1st charge iron.
First charge.....	100	100	200	100	100	500 2d charge iron.
Second charge.....	100	100	100	200	100	500 3d charge iron.
Third charge.....	100	200	100	100	100	500 4th charge iron.
Fourth charge.....	100	100	200	200	...	500 5th charge iron.
Fifth charge.....	100	200	100	200	...	500 6th charge iron.
Total coke.....	1000	900	900	1100	400	3300 total iron.

Melting done at one of the Cincinnati Stove Foundries, in the Truesdale patent cupola, with a Root blower and Connellsville coke :

	Lbs.		Lbs.
Coke in the bed	1,600	Iron on the bed	4,000
2 charges of coke, each	175	2 charges of iron, each	1,500
13 charges of coke, each	135	13 charges of iron, each	1,000
18 charges of coke, each	100	18 charges of iron, each	1,000
Total coke used.....	5,505	Total iron melted.....	38,000

Melting done at Pittsburgh in a No. 5 McKenzie cupola, with a Root blower and Pittsburgh coke:

Coke.	Isabell.	L. Superior.	Anthracite.	Chunks.	Sprews.	Plates.	Total.	Lbs.
1,000	400	400	400	200	.....	.....	1,400	} 4,000 1st charge.
	300	400	400	300	600	600	2,600	
200	400	300	300	200	.....	.....	1,200	} 3,000 2d charge.
	300	300	300	200	500	200	1,800	
200	200	300	200	.....	.....	.....	700	} 2,000 3rd charge.
	300	200	300	.....	400	100	1,300	
150	300	300	200	.....	.....	.....	800	} 2,000 4th charge.
	200	200	300	.....	400	100	1,200	
1,550	2,400	2,400	2,400	900	1,900	1,000	11,000	} Total iron melted.

Melting done at a Stove Foundry in St. Louis, Mo., in a straight cupola 50 inches in diameter, with Connellsville coke as fuel.

	Lbs.		Lbs.
Coke in the bed.....	1,500	Iron on the bed.....	3,500
First charge of coke....	150	First charge of iron....	2,000
Second charge of coke..	150	Second charge of iron..	1,500
Third charge of coke...	150	Third charge of iron...	1,500
Fourth charge of coke..	100	Fourth charge of iron..	1,000
Fifth charge of coke....	100	Fifth charge of iron....	1,000
Sixth charge of coke....	100	Sixth charge of iron....	1,000
Seventh charge of coke.	100	Seventh charge of iron..	1,000
Eighth charge of coke..	100	Eighth charge of iron...	1,000
Ninth charge of coke...	100	Ninth charge of iron....	1,000
Tenth charge of coke...	100	Tenth charge of iron....	1,000
Eleventh charge of coke,	100	Eleventh charge of iron.	1,000
Twelfth charge of coke.	100	Twelfth charge of iron..	1,000
Thirteenth charge coke.	100	Thirteenth charge iron..	1,000
Total coke used.....	2,950	Total iron melted.....	18,500

PERCENTAGE OF FUEL AND CASTINGS.

The following statements of melting was furnished to me by some of the leading stove manufacturers of Albany, N. Y., and represents the amount of iron melted, coal used, and castings produced in their foundries in the year 1876. The names of the companies furnishing these statements have been omitted by request:

First Foundry.

	Tous.	Lbs.
Gross amount of iron melted	2,059	1,087
Amount of stock melted	1,300	1,860
Amount of clean castings net	1,344	919
The percentage of cleaned castings produced to the total iron melted		57.70
Percentage of coal used in melting		15.55

Second Foundry.

Gross amount of iron melted	2,817	1,420
Amount of pig-iron melted	1,842	1,871
Amount of cleaned castings net	1,960	889
Percentage of cleaned castings produced to the total amount of iron melted		62.12
Percentage of coal used in melting		14.51

Third Foundry.

Gross amount of iron melted	1,818	930
Amount of pig-iron melted	1,123	42
Amount of cleaned castings net	1,128	1,407
Percentage of cleaned castings produced to total iron melted		55.42
Percentage of coal used in melting		15.17

Fourth Foundry.

Gross amount of iron melted	1,009	415
Amount of pig-iron melted	661	702
Amount of cleaned castings net	664	707
Percentage of cleaned castings produced to total amount of iron melted		58.62
Percentage of coal used		17.22

Fifth Foundry.

	Tons.	Lbs.
Gross amount of iron melted	3,328	84
Amount of pig-iron melted	2,118	521
Amount of cleaned castings net	2,216	987
Percentage of cleaned castings produced to total iron melted		56.35
Percentage of coal used in melting		16.12

The following statement was received from the largest Stove Foundry in the United States, as a statement of melting done last year :

	Tons.	Lbs.
Gross amount of iron melted	6,695	1,197
Amount of pig-iron melted	4,276	1,042
Amount of cleaned castings net	4,433	975
Net gain of castings over gross ton of pig-iron ..	166	1,442
Percentage of cleaned castings produced to total iron melted		58.41
Percentage of coal used in melting		15.08

The following statement show the percentage of fuel used and castings produced in the three different foundries in the year 1875 :

	Per cent.		Per cent.
Cleaned castings	61.81	Coal used	15.48
Cleaned castings	64.01	Coal used	14.70
Cleaned castings	55.96	Coal used	14.95

The following statement was received from a large stove foundry in Troy, N. Y., as statement of melting done in the year 1876 :

	Tons.	Lbs.
Gross amount of iron melted	2,009	987
Amount of stock melted	1,250	1,760
Amount of cleaned castings, net	1,294	819
Percentage of cleaned castings produced to total amount of iron melted		59.50
Percentage of coal used in melting		18.10

The following statements of percentage of castings produced and fuel used were furnished from different stove foundries in different parts of the country :

From Cincinnati, 1874.

Cleaned castings	65.00	Coke used	14.51
“ “	63.26	“	17.12
“ “	59.72	“	16.51

From Pittsburg, 1875.

Cleaned castings.....	70.11	|	Coke used	14.00
“ “	68.21	|	“ .....	15.75

From Baltimore, 1875.

Cleaned castings.....	69.13	|	Coal and coke used....	15.01
“ “	66.71	|	Coal used	20.00

From Philadelphia, 1875.

Cleaned castings.....	65.19	|	Coal used	18.72
“ “	60.49	|	“ .....	20.39
“ “	63.09	|	“ .....	19.78

From Louisville, Ky., 1875.

Cleaned castings.....	76.19	|	Coke used	27.36
“ “	67.08	|	“ .....	32.47

IRON LOST IN MELTING.

Very few foundrymen have ever made any accurate tests to ascertain how much iron they actually lost in melting. The majority of foundrymen take it for granted that they lose from ten to twelve per cent. I have made a great many careful tests to ascertain the exact amount lost in melting, and I find that the loss will vary according to the quality of iron melted and fuel used, etc. A No. 1 iron will lose more than a No. 2 iron, because it is more open and the carbon is not so combined with the iron, but is more in the graphite state, and is more volatile and easily burnt away. Old stove plate, shot-iron and other light scrap will lose more than a No. 2 iron, because there is more surface exposed to the heat before it is melted, and there is always more or less rust and dirt on it. Burnt iron will lose more than good iron, because the life has all been burnt out of it, and we have only the bulk of iron without the body. The loss will be greater when the

fuel is poor than when it is good, because more bulk of fuel has to be used ; the iron is melted higher up in the cupola, and is longer in melting. The loss is greater in one cupola than in another, because the pressure of blast is greater or less ; the cupola is charged different and melts different.

The loss is more when the iron is melted slow and dull than when it is melted fast and hot, because the principal loss takes place while the iron is being melted and is in the mushy state, and not after it has been melted and is in the molten state (a grate bar or an annealing box will all be burnt away and never melted). The loss will be greater in a machinery than in a stove-plate foundry, because their castings are heavier and there is not so much surface coated with sand as in stove-plate foundries, where the iron is cast in thin plates making a great deal of surface which has more or less sand on it, which is weighed and sold as iron.

By careful tests that I have made in different foundries, I have found the average loss to be about as follows : In stove-plate foundries, from two to eight per cent. ; in machinery foundries, with the average iron, from four to ten per cent. ; on old stove-plate and shot-iron, from twenty to thirty per cent. ; on burnt iron, from twenty-five to sixty per cent., according to how badly the iron was burnt.

The following test heats were made at the Franklin Foundry and Pipe Works, James Marshall & Co., proprietors, Pittsburg, Pa. :

Heat melted July 30, 1874, in the Truesdale patent cupola, with Kirk's chemical flux :

	Lbs.
Amount of iron charged was	38,150
Amount of iron obtained was.....	35,946
Amount lost in melting was	<u>2,204</u>

Heat melted July 31, 1874, in the Truesdale patent cupola, with a large percentage of lime-stone and slag tapped:

	Lbs.
Amount of iron charged was	35,150
Amount of iron obtained was	32,144
Amount lost in melting was	<u>3,006</u>

Heat melted September 9, 1874, in their common straight cupola, with Kirk's chemical flux:

	Lbs.
Amount of iron charged was	33,000
Amount of iron obtained was	32,561
Amount lost in melting was	<u>439</u>

Heat melted September 14, 1874, in their common straight cupola, with lime-stone as a flux:

	Lbs.
Amount of iron charged was	33,000
Amount of iron obtained was	31,235
Amount lost in melting was	<u>1,765</u>

The following test heats were made at the Vulcan Iron Works, Wilkesbarre, Pa.:

Heat melted December 21, 1875, in their common straight cupola, with Kirk's chemical flux:

	Lbs.
Amount of iron charged was	13,500
Amount of iron obtained was	13,370
Amount lost in melting was	<u>130</u>

Heat melted December 24, 1875, in their common straight cupola, without any lime-stone or other flux:

	Lbs.
Amount of iron charged was	13,300
Amount of iron obtained was	12,799
Amount lost in melting was	<u>501</u>

The following test heats were made at the Wyoming Valley Manufacturing Co.'s Foundry, Wilkesbarre, Pa.:

Heat melted December 29, 1875, in their round bosh cupola, with Kirk's chemical flux :

	Lbs.
Amount of iron charged was	3,700
Amount of iron obtained was	3,645
Amount lost in melting was	55

Heat melted December 30, 1875, in their round bosh cupola, with oyster shell flux :

	Lbs.
Amount of iron charged was	6,200
Amount of iron obtained was	5,813
Amount lost in melting was	387

The following test was made at the Phœnix Foundry, Cincinnati, Ohio, January 25, 1875 :

	Lbs.
Amount of pig-iron charged was	6,100
Amount of scrap charged was	1,400
Amount of fine rattle-barrel iron was	2,000
Total amount charged in cupola	9,500
Total amount obtained out of cupola	8,750
Total amount lost in melting	550

The following test was made at the Baldwin Locomotive works, Philadelphia, Pa., June 26, 1874, in melting shot-iron in a thirty inch straight cupola, with Kirk's chemical flux :

	Lbs.
Amount of shot-iron charged	2,240
Amount of pig-iron obtained	1,797
Amount of iron lost in melting	443

The following test was made at the American Stove and Hollow-ware Co.'s Foundry, Philadelphia, Pa., July 15, 1874, in melting a lot of badly burnt iron in a twenty-four ton McKenzie cupola, with the Lawrence tuyere in it, and Kirk's chemical flux :

	Lbs.
Amount of annealing pots charged	2,200
Amount of pig-iron and scrap obtained	1,540
Amount of iron lost in melting	660

I do not consider this a fair test, as the cupola was entirely too large for the amount of iron melted.

Test heat made in the foundry of the Jackson & Woodin Manufacturing Company, to ascertain the wastage of iron. Tests were made under immediate supervision of their foundry formen:

Heat melted March 24, 1876.

	Lbs.		Lbs.
Lump coal.....	2,002	Castings	5,029
No. 2 pig-iron....	6,069	Gates and scrap.....	469
Limestone.....	160	Cinder scrap.....	287

Total iron put into the cupola.....	6,069 lbs.
“ out of “	5,785 “

Lost in melting.....	284 lbs.
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or say 4.7 per cent., or 105 lbs. per 2,240 lbs.

Heat melted March 25, 1876.

	Lbs.		Lbs.
Lump coal.....	2,002	Castings.....	4,380
No. 2 pig-iron....	6,069	Gates and scrap.....	1,036
Kirk's chemical flux used.		Cinder scrap.....	504

Total iron put into the cupola.....	6,069 lbs.
“ out of “	5,920 “

Lost in melting.....	149 lbs.
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or say 2½ per cent., or 56 lbs. per 2,240 lbs.

We hereby certify that the above experiments were carefully and impartially made at our works as above stated.

THE JACKSON & WOODIN MANUFACTURING Co.,

BY C. G. JACKSON,

Vice-President.

MELTERS.

In traveling through the country and visiting different foundries, I have discovered that there are in existence, four different classes of melters. The first is

the Old Professional Melter who does not know anything about a modern cupola, and is too old to learn. He involves everything about the cupola in mystery, and makes out that it is an awful accomplishment to be able to run a cupola. Next comes the Smart-Alic Melter, who knows a little about a cupola, and has some good ideas and a great many bad ones; he has no regularity about what he does, and has a great deal of trouble with the cupola, but he always has a good excuse for everything that goes wrong, so the boss thinks he is all right. Next comes the cheap melter, who does not know anything about a cupola, and does not make any pretence to know anything, but works along like a machine and gets his wages every Saturday night. He wastes a fearful lot of fuel and iron, and the molders lose heaps of castings on his account, but he works cheap and is kept on. Next comes the Practical and Scientific Melter, who does not make any great pretence to know anything, but who understands his business and attends to it; he does everything by rule and always has good hot iron. I have described these four melters at length, so that by comparison of them, the melters can see what is the cause of their trouble, and the foundrymen how they are imposed upon by melters.

THE OLD MELTER.

Scarcely one owner of a foundry in a hundred understands the melting of iron, either practically or theoretically, and there is not one foundry foreman in fifty that could take a cupola and run off a heat successfully. If you speak to them about melting iron, they will tell you that they have an old melter that has melted iron for twenty years, and knows all about melting iron, and is doing the best melting that is done around this

part of the country. The old melter is generally a man whose father was a melter, and whose grandfather used to own a foundry, and all he knows about a cupola and melting iron was handed down to him by tradition from his grandfather. If you go on to the scaffold when the cupola is being charged, you will find the old melter standing at the charging door of the cupola with a look of mysterious wisdom plainly depicted upon his countenance. Every piece of iron is handed to him by his helpers and he throws it into the cupola. If the helpers chances to throw a piece of iron into the cupola, the old melter will take his bar and roll it over or twist it around a little; if he does not move it around with his bar, and there is one dull ladle of iron in the heat, it is all laid to that particular piece of iron that was not charged right.

The old melter lights his fire and charges the iron at a certain time every day, regardless of wind or weather. The fire is not half burnt up one day and the bed is all burnt up the next day, the result is, that on one day the blast has to be on for half an hour before any iron can be melted, and the next day the iron will be down in five minutes after the blast is on, and so dull that it cannot be used. If you ask the old melter why the cupola melts slow, or why the iron is dull, he will tell you that he has attended cupolas for *twenty years*, and they are liable to take those kind of spells any time—a cupola won't do to bet on, boss; or he may squint one eye, give you a knowing look, and remark that we are going to have a change of weather; I can see it in the cupola, for the changes in the atmosphere always affects the melting of iron. If the owner of the foundry hears that his neighbors are melting ten lbs. of iron to one lb. of fuel, he tells the old melter about it, and wants him to do the same. The old melter declares that iron cannot be melted ten to one, and that there is not a foundry in the country doing it; but if the boss insists

that it must be done, the old melter goes to work at it and will do as well as his neighbor, and probably a little better. If an accurate account is kept of all the coal or coke charged in the cupola for a year, and compared with the coal or coke bought and delivered in the yard for the same year, the boss will probably find that he is short two or three hundred tons. If he asks the old melter what has become of this two or three hundred tons of coal or coke, the old melter will declare that he only used one lb. of fuel to ten lbs. of iron, and that the account he has given is correct, for he weighed all the fuel that went into the cupola except a few little pieces that he put in to fill up the holes in the bed before he commenced charging, which he did not bother about weighing. If the old melter takes a day, the whole shop must lay off, for the cupola is a mystery, and no one dare undertake to run off a heat except the old melter. Thus it goes on from time to time, and the old melter is the Lion of the foundry.

PRACTICAL AND SCIENTIFIC MELTER.

The practical and scientific melter, is the melter who understands his business, and attends to his business; he chips out his cupola, and daubs it up in proper shape; he puts up the iron bottom, and sees that it fits close and solid, and is properly supported; he puts in the sand-bottom, and sees that it is packed solid and even, and has the proper pitch, without any hills or hollows in it; he puts in the front so that it never blows out, and he sees that the spout is in proper shape; he always has the tapping-bars drawn down to a sharp point, so that he can tap with ease, and have the tap-hole large or small; he has his bod-clay thoroughly

mixed, and his bod-sticks always handy, and in good shape. When he wants to stop-up, he takes the bod-stick and sees that there is a bod on it in proper shape; he then puts the bod right over the tap-hole and gives it a sudden downward pressure, and stops the iron with ease. He puts in the shavings to light the fire with, and sees that they are properly spread over the sand-bottom, so as to light the wood evenly—the wood is cut short and split, and every piece is laid in the cupola, in the proper shape, so as to give the fire the best possible chance to burn, and light the coal or coke evenly; he selects a few small pieces of coal or coke, that will light easily, and puts them in on the wood, he then puts in the bed. If the cupola has a good draft, he puts in all of the bed before the fire is lit; if the cupola has a poor draft, he only puts in part of the bed before the fire is lit, and the balance after the fire has got thoroughly started. He sees that the bed is evenly burnt and level on top, before the iron is charged; he charges the iron compactly together, so that it will get the good of all the heat from the fuel; he sees that every charge of iron is level and even on top when all in; he sees that every charge of fuel is properly distributed over the iron, so that it will melt the next charge of iron properly, and at an even temperature; he increases or diminishes the amount of coal or coke, in the bed, or between the charges of iron, at the rate of twenty-five or fifty pounds at a time, until he finds the exact amount required; he increases or diminishes the amount of iron on the bed, or in the charges, at the rate of one hundred pounds at a time, until he finds the exact amount of iron that can be melted in that particular cupola, with the smallest percentage of fuel; he then continues that charging without any variation; if he gets in a poor lot of fuel, he may increase the bed and charges of fuel a few pounds; or, if the fuel is extra good, he may decrease a few pounds, but always

with caution and safety he watches the direction the wind blows, and notes the effect that a north, south, east or west wind has upon the draft of his cupola, and he lights his fire accordingly, so as to have the bed burnt as near alike, every day, as possible; he inspects the blast-pipe and tuyeres, every day, to see that there are no holes in the pipe through which the blast may escape, and to see that the tuyeres are in proper shape, so that the blast will not escape up behind and through the lining, in place of through the stock; he notices the exact effect of the blast upon the cupola, and he knows when he is not getting enough blast, and at once complains to the foreman, or engineer; he looks around the shop, toward the last of the heat, and sees or asks the foreman how much more iron is wanted; he then looks into the cupola, and if he thinks there is not enough iron in to pour off with, he throws in a little more, before the stock gets too low to melt it. The practical and scientific melter does everything according to rule, and not by guess, and the foundrymen can depend upon him having good hot clean iron, every day, if it is possible to make it in his cupola.

SMART-ALIC MELTER.

The Smart-Alic melter is generally a very pompous and very important man in his own mind: he is always ready to give his opinion on everything, and more especially on the cupola. He will tell you all about the cupola he was running before he came here, and what good luck he had with it. He will tell a new molder all about how well he gets along here, and he may tell him about that bad heat he had the other day when the engineer let the belts on the fan get loose, and he had no blast. He is always full of business and flying

around in a hurry, especially when the boss happens to be around. He picks out the cupola and daubs it up in a hurry, and gets out of it as quickly as possible, because it is a dirty job, and he says that it needs a new lining, anyhow. He puts up the iron bottom, and it may be twisted or warped a little, and will rock on the prop. He never wedges it or puts in an extra prop to make it solid, for he says the sand bottom makes that all right. The stock in melting may hang a little and come down with a lurch, and rock the iron bottom on the prop and crack the sand bottom and let the iron run out around the edges of the bottom; Smart-Alic then jumps around and swears at that *damned* old crooked bottom—we ought to have had a new one long ago—and every one gets around the cupola with a bucket of water, a shovelful of sand or a ball of clay, and the bod sticks. Every one tells how it ought to be stopped; they never think of taking off the blast; the iron is melting all the time, and before they get it stopped from running out through the bottom, it is running out at the tuyeres. Some one halloos, *tap out* the iron running out at the tuyeres. Smart-Alic then rushes around, grabs up the tapping bar, jabs it into the front in a hurry, and probably he will knock out the whole front and the iron runs out all over the floor, and finally the bottom has to be dropped. He puts in his sand bottom, and will probably ram it so hard in spots that the iron will not lay upon it, but will boil and cut up the sand, and will make a dirty iron, if it does not cut through and run out; or he may have it so soft in spots that the iron will run through it, or so low on the back side that the iron will not run out at the front. He takes shavings to light the fire with up to the charging door, and throws them in; it does not make any difference whether they are spread over the sand bottom or not, for they will burn, anyhow. He puts the wood in in long pieces, for he says the cupola has a

good draft and it will burn a long piece of wood just as well as it will a short piece, and there is no use of cutting it. He throws the wood in from the charging door, on its end, and it may dig a hole through the sand bottom and let the iron run out. Smart-Alic will then fly around and swear that the melter that run that cupola before him, let the iron run out and burnt the iron bottom full of holes, and he cannot keep the iron in it without a new iron bottom. One-half of the wood will be above the coal or coke after the bed has been put in. That is all right; the wood put in that way gives the fire vent and makes it burn better; he says that little bit of wood that is above the coal or coke does not cost anything. He does not care if the fire is all on one side of the cupola, for he says that the blast will soon fix that after it is put on. If he is told that he is using too much fuel and he must use less, he will reduce it by taking four or five hundred pounds off the bed, and one or two hundred pounds off each charge of fuel, the first slap. If he is told that it might be better to put the iron in the cupola in larger charges, he will add another ton or two of iron on the bed, and will increase each charge of iron fifteen or twenty hundred pounds, the first slap.

This way of decreasing the fuel or increasing the charges of iron is generally a failure, and the result is dull iron. Smart-Alic will then strut around the shop, pull down his vest, and tell you that he knew that cupola would not make hot iron charged in that way, for he has studied and watched it close, and knows just what it will do; and it won't make hot iron with any less fuel than he is using; and if you want to melt with less fuel, says he, you must get a new cupola, for that darned old thing is played out, anyhow. He never pays any attention to whether the wind blows from the north, south, east or west, because he does not melt iron by the way the wind blows, but by a fan blast, and

that fan will make just as much blast if the wind blows from the north as it will if the wind blows from the south ; he would never have any trouble in melting if the engineer would keep the belts, on the fan, tight, and give him a good blast. He never looks at the blast-pipe to see if there are any holes in it through which the blast may escape, because that is not his business ; and he has too much to do now, for all the wages that he gets, without fooling around an old blast-pipe. He never looks at the tuyeres to see if the blast escapes up back of or through the lining, for it is no use, for he put them tuyeres in right when he lined up, about a year ago, and he knows that they are all right. He charges the cupola so irregularly that he cannot tell anything about whether he has enough blast or not, but he is eternally growling about not having any blast, and his growling becomes an old song, and the foreman, or the engineer, never pays any attention to him. He never sharpens the tapping-bars, but has them blunt on the end, and in tapping he shoves the old bod into the cupola instead of cutting it away, and the iron forces it back into the hole and stops the iron from running out ; he takes the bar and jabs it into the hole and works it around, and will probably knock out the front ; he will then swear that that sand is not fit to put in the front with, because it cracks and crumbles when the heat strikes it ; he says that old spout is good enough for to-day, for he is a little behind time and cannot fool around making a new spout every day ; he never pays any attention as to how his stopping-clay is, until he wants to use it, then he finds that it is too dry and he throws a little water on it and mixes it up in a hurry and has it wet and dry in spots ; he has his bod-sticks laying around anywhere, and he seldom has a bod on more than one stick at a time ; when he wants to stop-up, he takes the bod-stick, flourishes it around, the bod drops off into the ladle of iron, and he rams the stick into the

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tapping hole, the iron flutters and squirts out around the stick, and some one tells him that he has no bod on that stick, then he flies around and makes two or three unsuccessful attempts to put on a bod in a hurry ; he tells every body to stand back and give him a chance—that they will crowd up around that cupola until they all get burnt some of these times ; he will finally get a bod on, and get the cupola stopped-up, after the ladle has run over, and the iron runs all over the floor, or the bod-clay may be so wet that it cannot drop off the stick, and in stopping-up he will shove the bod up under the stream, the iron shoots out over the bod and burns his hands, he drops the stick and swears that those stopping-sticks are too short, and he must have some new ones, for he is not going to get burnt every day stopping-up. The foreman makes out his estimate of how much iron he wants that day, and gives the estimate to the melter to charge by ; Smart-Alic looks at it, and says to himself, well, we had five hundred pounds too much iron yesterday, and I am not going to have five hundred pounds too much to-day to lug out and pour in the pig-bed, so he charges five hundred pounds less than he is ordered to do, the result is, that they are five hundred pounds short that day ; the foreman thinks that he made his estimates too low, and the next day he adds a little to make up for what he was short the day before ; he then gives his estimate to the melter ; Smart-Alic looks at it and says to himself, that he was short five hundred pounds yesterday, and he is not going to be short to-day, so he charges five hundred pounds more than he is ordered to do, the result is, that they have ten or fifteen hundred pounds more than is wanted, and no one is to blame. Smart-Alic does not have all of these troubles, every day, but he has some of them most every day ; he will have from two to three bad heats a week, and will blame them on the blast, on the atmosphere, on poor fuel, on that old, worn out cupola ; and, in fact, he

will blame the bad heats on most anything but himself. I have not made up my mind yet whether the old professional melter, or the Smart-Alic melter, is the worst, but I have made up my mind that they are both a nuisance about a foundry.

N. B.—Smart-Alic, with all his faults, has his good redeeming qualities, for he is generally a philanthropist; he often supports one or two families out of the dump; he helps the poor fire-brick manufacturer to sell his brick, and the poor dealer in fire-sand and fire-clay tells the foundryman that he has got such a good melter; if it was not for Smart-Alic, the poor patent cupola man would die of starvation, but if Smart-Alic was to “pass in his checks,” the engineer and the flux-man would be happy.

HOT-BLAST CUPOLAS.

Not only have the foundrymen endeavored to imitate the blast furnacemen in the adaptation of limestone as a flux for their cupolas, but they have also attempted to imitate them in the adaptation of a hot-blast for their cupolas, and with this view several different styles of cupolas and ovens for heating the blast have been constructed, but they have generally been abandoned as a failure. The best hot-blast arrangement for a cupola, that I have seen, is that represented in fig. 19, in which *DD* represent the cupola in which the stock is charged and the iron is melted; *BB* represent the arched flue that connects the top of the cupola with the ovens *EE*, and through which the heat passes into the oven from the cupola *D*, as shown by the white darts; it then passes down around the coil of the pipes *CC*,

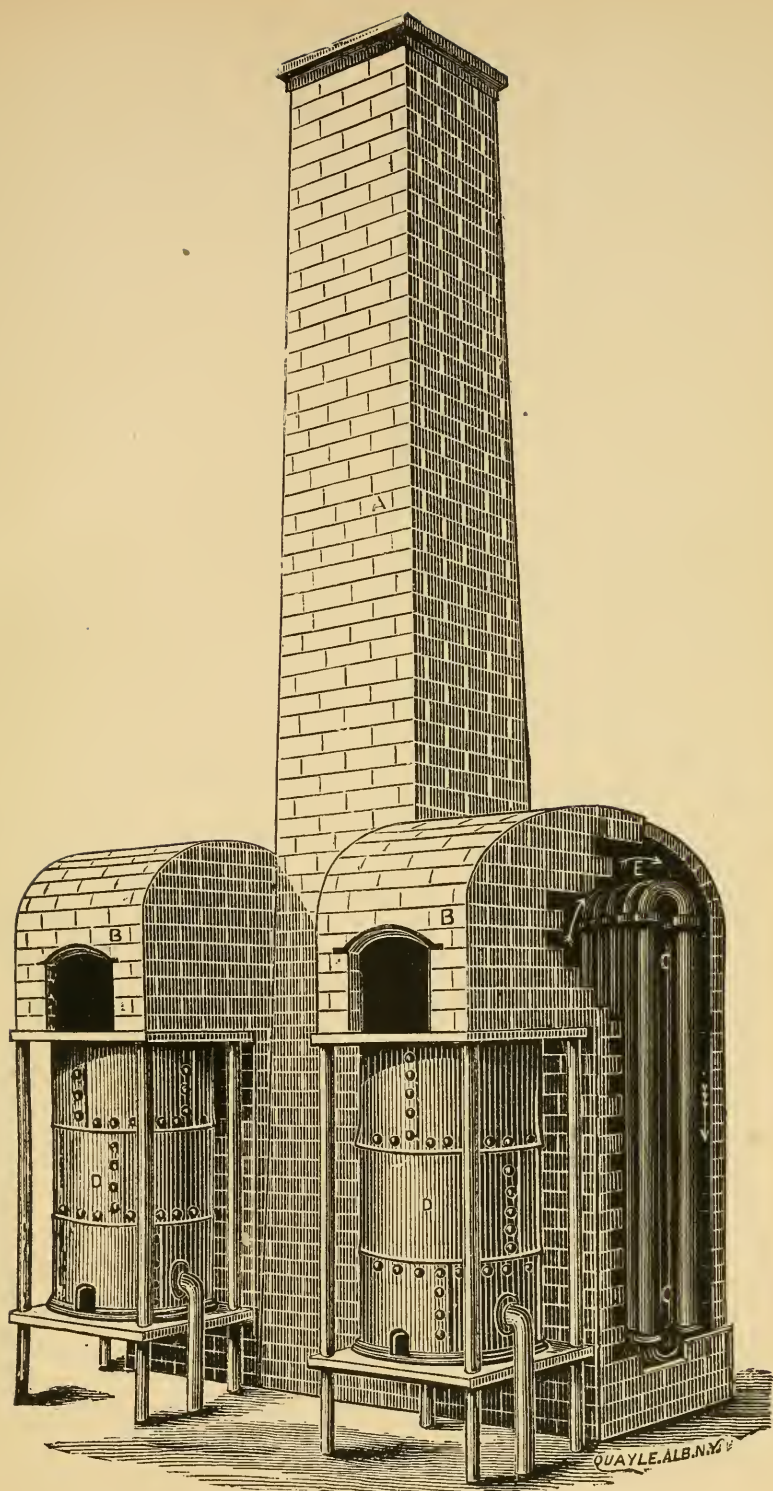


Fig. 19.

and enters the flue or stack *A* at the bottom. The cold blast is forced through the pipes *CC*, which are heated by the flame from the cupola, and when the blast enters the cupola at the tuyeres it is hot. This pair of cupolas were erected by the Foundry Company of Jagger, Treadwell & Perry, of Albany, N. Y., with a view of saving fuel and improving the quality of the iron melted, but experience proved them to be a failure, for more power was required to force the blast through the coils of pipe, and it took some time to get the pipe hot enough to heat the blast, so that the heat would be half off before the blast became hot enough to do any good. The coils of pipe were expensive to keep up, and although some little fuel was saved in the cupola, yet it was not enough to pay the expense of keeping up the pipe, and this hot-blast arrangement was abandoned as a failure.

Several hot-blast cupolas have been built, with large stacks on top of them filled with coils of pipe, and the pipe heated by the flame and waste heat from the cupola; the cold blast was forced in at the top of the coil of pipe, and as it passed down through the pipe it became hot before reaching the tuyeres. This hot-blast arrangement was like that of fig. 19, expensive to keep up, and has generally been abandoned.

Several attempts have been made to draw hot air from the stack of the cupola and again force it in at the tuyeres. To do this, the supply pipe for the fan or blower has been connected with the stack just above the charging-door, and the hot air drawn from the cupola and forced through the fan or blower and into the tuyeres. This arrangement has in every instance been a failure, for the hot air from the cupola soon heats the fan or blower, and burns off the belts and ruins the machine.

Whether or not a hot blast will improve the quality of pig-iron when remelted in a cupola, has not been determined; but it has been satisfactorily demonstrated

that the blast cannot be economically heated with the waste heat from the cupola, for, in order to heat the blast, we must pass it through coils of hot pipe, and the heat from the cupola is not intense enough, before the blast is put on, to heat the pipe, and the cold blast must be put on in order to create a flame from the cupola and heat the pipe; and when the cold blast is passing through the pipe to the cupola, it takes some time to heat the pipe with the flame from the cupola, and in melting a few tons of iron the pipe would not become sufficiently hot to heat the blast before the iron would all be melted; and even if the pipe were sufficiently heated to heat the blast, toward the last of the heat, the often sudden cooling of them when the cupola was dumped, would soon break and crack the pipe, which would have to be replaced with new ones to avoid the escape of the blast; and the advantage gained by this kind of a hot-blast will not pay the expense of keeping up the pipe.

The only way that the blast can be thoroughly heated and the pipe prevented from breaking, is, to heat the pipe in an oven and keep them continually hot, the same as at a blast furnace. This arrangement cannot be economically applied to small foundries where the cupola is only in blast for two or three hours each day; but it might be applied in large foundries where one cupola after another is put in blast, so that one or more cupolas are kept in blast all day. For small foundries a hot blast might be arranged by building a furnace and closing up the ash-pit, and blowing the cold blast into the ash-pit and allowing it to pass through the fire before entering the cupola. This arrangement would be a success so far as heating the blast, but the question would be; whether volume enough of blast could be forced through the fire to supply the cupola without putting out the fire or using too much fuel to heat the blast. I do not know that this arrangement has ever

been tried for a cupola, but it has been tried for a reverberatory furnace, with anthracite coal, and works successfully; and some of our enterprising foundrymen might do well to try and apply it to their cupolas.

REVERBERATORY FURNACES.

The reverberatory furnace is the best furnace for melting and mixing iron on the large scale for foundry purposes. They are next to the crucible for making a good homogeneous foundry metal, and are used in all foundries where heavy work is made that requires a good homogeneous iron and great strength such as cannon, rolls for rolling mills, house and bridge beams, etc. Iron melted in the reverberatory furnace is cleaner than iron melted in a cupola, and it will flow into the mold like molten lead, and will make a casting more free from blow holes; but in foundries where light work is made and hot fluid iron is more of an object than the strength of the castings, the reverberatory furnace has, as a general thing, been replaced by the cupola furnace, which has the advantage over the reverberatory furnace of melting iron faster, hotter, and with less fuel; but the iron in the reverberatory furnace is not melted in contact with the fuel as in the cupola, but it is melted by the flame or gases from the fuel, and it does not take up the sulphur and other impurities from the fuel as it would do if melted in contact with the fuel. There are several different kinds of the reverberatory furnaces, but they only differ in the minor points of their construction, and all agree in the one principle of throwing a highly heated flame against the iron. These furnaces are constructed of fire-brick laid in fire-clay, and the whole furnace is surrounded with cast-iron plates bound together with

cross ties or rods, and they are sometimes built of common brick and lined with fire-brick, and the whole bound together by iron cross-ties and binders. But the furnace surrounded with the cast-iron plates is the best and the cheapest furnace in the long run. In the reverberatory furnace the bridge wall that separates the hearth and the grate-bars is from six to ten inches high above the hearth and twenty or twenty-five inches above the grate-bars. The grate-bars are three or four feet long and the grate or fire-place is as wide as the furnace and sometimes wider. A large slide door is put in just back of the bridge wall for charging the iron; this door may be in the top of the furnace or on one side.

The iron to be melted is all piled in the furnace on the hearth just back of the bridge wall before the fire is lit. The stack of the furnace should be high enough to give a good strong draft, and it should be fitted with a damper on top of it so as to regulate the draft. The walls of these furnaces should be very thick so as to be as bad a conductor of heat as possible. All the cracks and openings around the door and in any part of the furnace should be carefully stopped up with clay or loam when the furnace is in operation, so that no cold air will be admitted into the furnace except through the grate and fire. In the working of these furnaces a great deal depends upon the bridge wall between the hearth and the fire, for if the bridge wall is either too high or too low the heat will be wasted and hot iron cannot be made. The best fuel for the reverberatory furnace is the bituminous coal. Anthracite coal or coke is used in some parts of the country as fuel for this class of furnaces, but it is not near so good as the bituminous coal. When the anthracite coal or coke is used, the ash-pit of the furnace is closed up and a mild blast turned into the ash-pit so as to supply oxygen more rapidly and create more flame from the

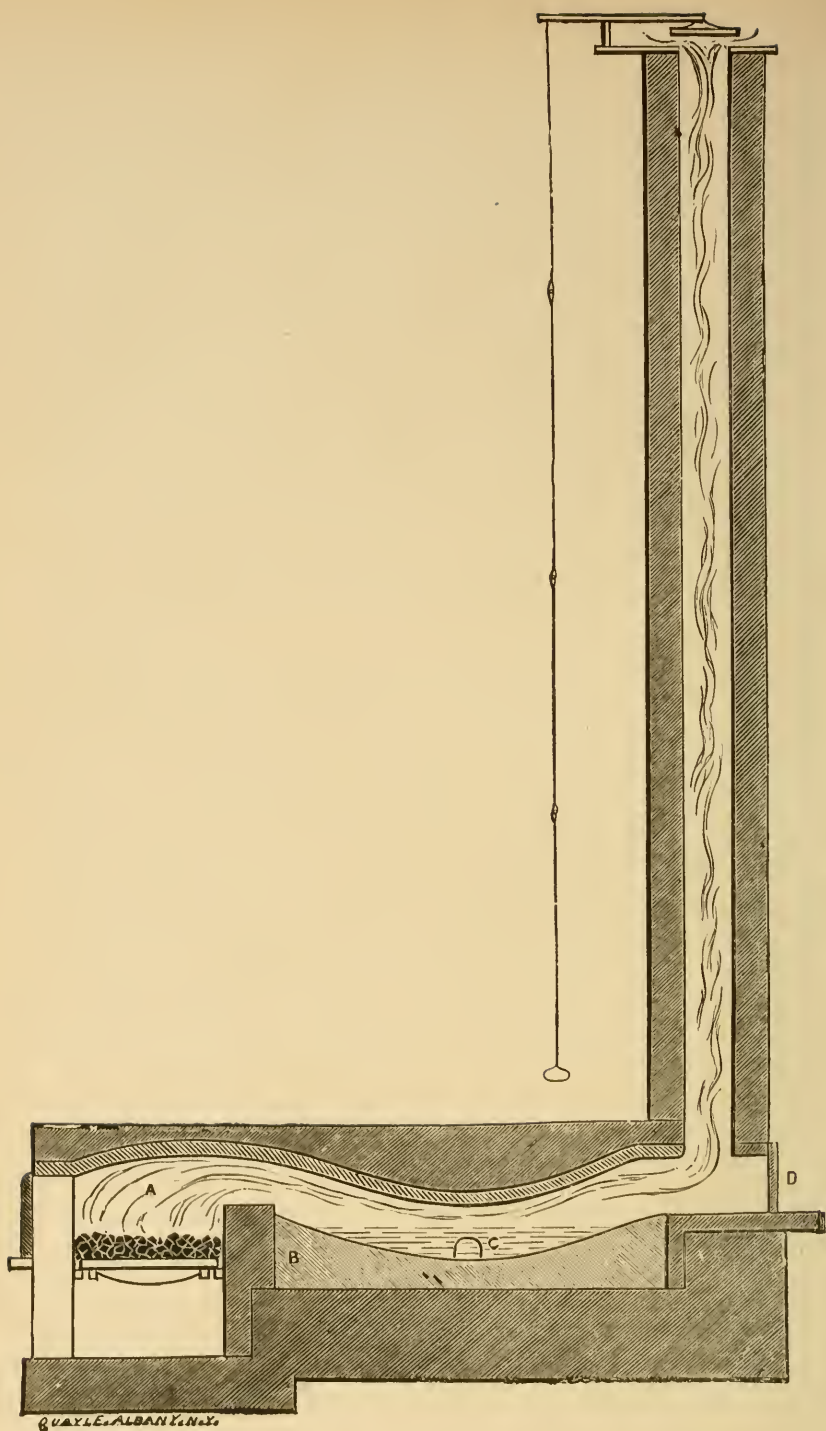


Fig. 20.

fuel. When the anthracite coal is used, a large amount of fine ashes will be carried over the bridge wall and deposited on top of the molten iron; these ashes will prevent the iron absorbing the heat, and where it is desirable to make very hot iron, these ashes should be occasionally skimmed off through an opening made in the furnace for that purpose. Wood is not at all qualified for use as a fuel in this kind of a furnace where no mineral coal can be obtained; charcoal may be used as a substitute for it.

Fig. 20 represents a sectional view of the reverberatory furnace that is generally used in foundries for melting iron. In this furnace *A* represents the grate or fire-place; *B* the hearth upon which the iron is melted; *C* the tap-hole at which the iron is drawn out of the furnace, and *D* the door through which the refuse is taken out and the furnace repaired. The hearth *B* is generally put in with fire sand or a mixture of sand and fire clay, or it may be built of brick and nearly covered with fire sand or clay. The pig-iron or iron intended to be melted is piled on the hearth just back of the bridge wall, and as it melts it flows into the basin or hollow in the centre of the furnace where it remains until it becomes sufficiently heated to run into the molds. It is then drawn out at the tap hole *C* into ladles for small work, but for large work it is generally run from the furnace through a trough directly into the mold. In foundries where large quantities of iron is melted for heavy castings and it is desirable to mix the iron thoroughly by polling it, the hearth of this furnace is made as wide as the grate or fire-place, and the fire-place may be five or six feet wide, but in foundries where only small amounts of iron is melted, and it is desirable to make the iron very hot and fluid for light work, such as malleable castings, the hearth is only two or three feet wide, while the fire-place is five or six feet wide. By reducing the width

of the hearth in this way, the heat is more concentrated on the iron and will make a hotter and more fluid iron.

Fig. 21 represents a sectional view of another style of reverberatory furnaces, that is commonly used in foundries where light castings is made, and it is desirable to make very hot iron. In this figure, *A* represents the grate, or fire-place, in which the fuel is burned; the iron intended to be melted is piled on the hearth of the furnace, just back of the bridge wall, through a large door in the side of the furnace, as indicated by the dotted lines; this door is raised and lowered by a lever on top of the furnace, as shown in fig 21. In charging the iron in the furnace, it should be piled on the hearth eighteen or twenty inches back from the bridge wall, so as to cause the flame from the fuel to dip over the bridge wall, and strike the iron. As the iron is melted on the hearth it flows down into the basin *C*, and all the dirt or sand on the iron is left on the hearth from where it may be removed through the large door. After the heat, the molten iron is held in the basin, at the bottom of the stack, where the heat is the most intense, until it is sufficiently fluid to run into the molds. It is then drawn out into ladles, or may be run from the furnace directly into the mold. This furnace is considered to be a better furnace for making hot iron than the furnace, fig. 20. In constructing this furnace, the grate, or fire-place is generally made five or six feet wide, and the flue, at the bottom of the stack, is only two or three feet wide, so as to concentrate the heat upon the iron, and also to concentrate the iron, so as not to expose so much surface of molten iron to the oxidizing action of the flame. Less fuel is required for this furnace than for any of the other kinds of reverberatory furnaces.

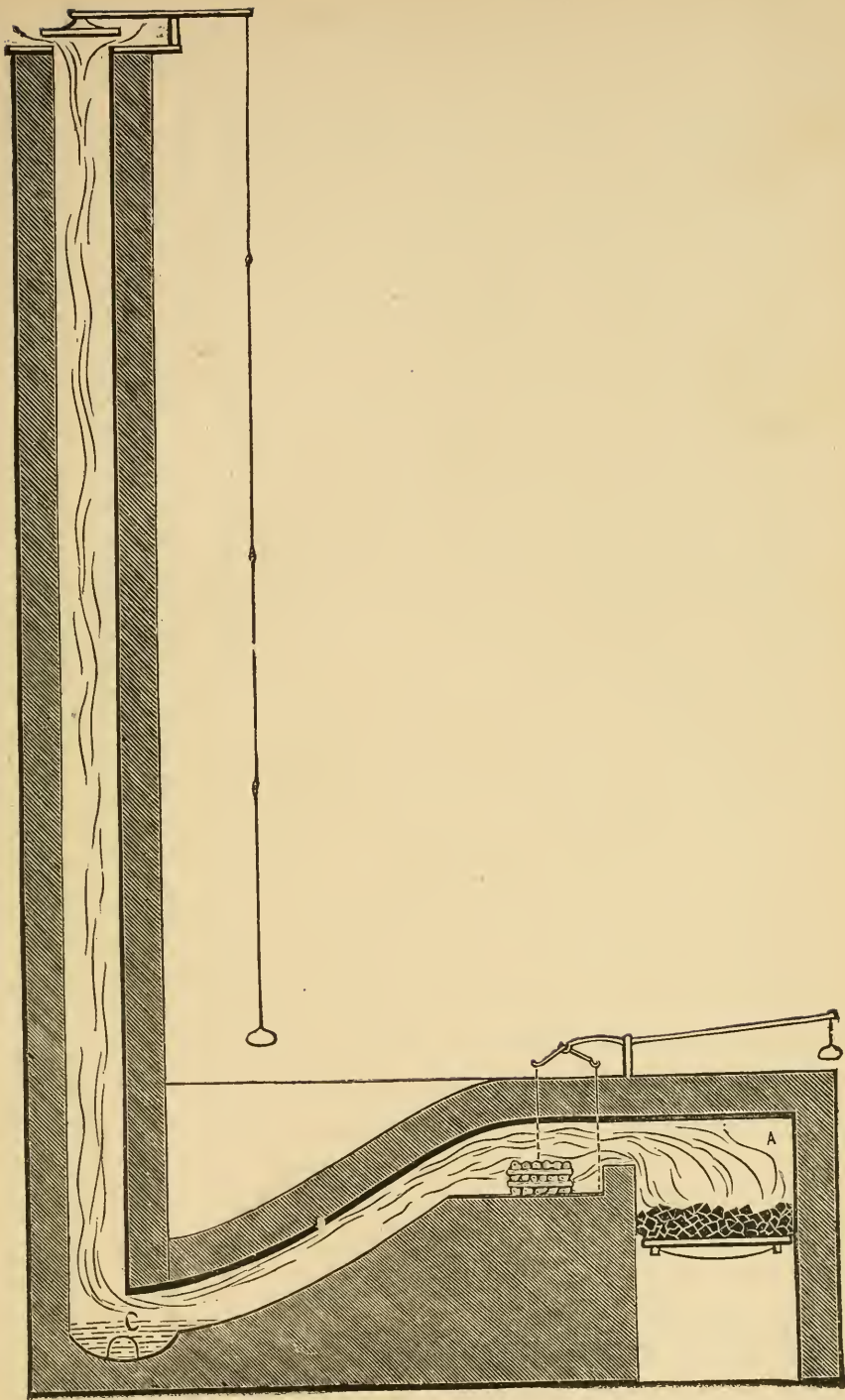


Fig. 21.

YOUR NEIGHBOR AND YOU.

Some foundrymen wonder how it comes that their neighbor can sell castings so much cheaper than they can and make a living. They say that they buy stock as cheap as their neighbor, and they do not pay their men any higher wages, and they have got just as good molders, and they put up as large a day's work as their neighbor's molders do; their patterns do not cost any more than they do in any other foundry, and their neighbor must be losing money and will break up in a short time. They never look at the cupola; they think that is a foundry fixture that is alike in every foundry, but there is just where the difference comes in. Your neighbor sees that his cupola is constructed right, and charged and worked right, and by so doing he will undersell you and still make a good profit. If a practical foundryman was to travel through the country and examine the cupolas in use at the present time, he would be surprised to see how unscientific and how little judgment has been used in their construction. He will find cupolas sixty inches in diameter, and only seven or eight feet high. The next cupola will be twenty inches in diameter and fifteen or twenty feet high. The next one will be built like a big tub, larger at the top of the stack than at the bottom of the cupola, and the heat all escapes up the stack. The next one will only have one or two small tuyeres; and the next one will be all tuyeres. One cupola will have scarcely any blast, and the next one will have three times as much blast as it ought to have. The next one will be an old cast-iron stave cupola with one-half of the staves broken, and more blast escaping through the caisson than is going up through the stock. The next one has not been lined for ten years or more, and the lining is all cracked and shaky, and one-half of the blast escapes

up between the lining and the caisson; and so it goes all through the country, and yet we boast about the advancement we have made in the construction of furnaces and the melting of iron. There is no more judgment used in the selection of a melter than there is in the construction of cupolas. Foundrymen generally believe in cheap labor, and they consider the melter an unimportant man, and they will hire some cheap man that does not know enough about the laws of combustion to start a fire in a cook stove, and they will give him full charge of the cupola. He gets a few instructions when he first takes charge of the cupola, and after that he is allowed to do as he pleases and use his own judgment, and he has no more judgment than a shoemaker's hog. He will pick out the cupola three times as much as he ought, and then daub on two or three inches of mud; and he will generally have to put in a few new bricks every day. He has to put in three or four feet of new lining (just above the tuyeres) about once a month. He will use twice as much wood in starting the fire as is necessary, and throw it all on one side of the cupola. He will put the bed in too high, and use twice as much fuel between the charges of iron as is necessary. This extra fuel has all to be burnt up before the iron can come down to the melting point. The mud is too heavy to hang on the brick lining, and breaks loose and settles down over the tuyeres, and prevents the iron from melting, and it takes two or three hours to run off a heat that should be run off in one hour; and there is more wastage of iron, more fuel has to be used under the boiler, and there is more wear and tear of the machinery and belts. This poor, cheap melter will use and cause to be used twenty dollars worth more stock, in the melting of a few tons of iron, than is really necessary to be used. Yet the foundryman never notices any of these things; all he thinks of is the twenty-five or fifty cents less per day that he

pays this man than he would have to pay a good man. The melter has the dirtiest and most disagreeable job about the foundry; in the winter he has to stand in the cupola and pick it out, and the draft of the cupola makes it the coldest place about the foundry. He has to handle the cold mud with his hands to daub up with. The cupola often stands outside, and he has to be out in all kinds of weather to charge up. In the summer he often has to go in and pick it out before it is cold, and he has to be around where it is the hottest, charging and tapping out—and a good man is not going to attend a cupola unless he gets better pay than he can get for more agreeable work. The melter is generally the poorest paid man about the foundry, and he is often the poorest man about it. This should not be so; for the melter is the most important man about the foundry. It makes no difference how much care a molder may take to make a nice, clean mold; he cannot make a nice casting without good, hot, clean iron; and it makes no difference how much expense the foundry company may go to for the latest improved fan or blower, or for the best cupola; for the best cupola in the world will not do good melting unless it is charged and worked right, and no man should have charge of a cupola but a good, sober, sensible man, that has some judgment of his own. The melter in a small foundry should receive as much wages as a molder, and the melter in a large foundry should receive more wages than a molder. If he is not worth as much or more than a molder, he is not worth having about the foundry. No foundry foreman is a competent man to have charge of a foundry who does not thoroughly understand the working of a cupola and the melting and mixing of irons. He should be able to take the cupola and run off a heat as well as the melter. No foundryman, who has not thoroughly investigated the management of cupolas and the melting of iron, has any idea how

much money can be and is wasted by the improper construction and management of cupolas. If foundrymen would pay more attention to their cupolas, they would be able to compete with their neighbors in the market; for a diligent study of the construction and management of cupolas and furnaces will not only enable the foundryman to obtain the most valuable iron from a given material, but it will enable him to modify his products in accordance with the state of the market and the wants of the times. Perhaps in no other branch of business is rational and skilled management so indispensable an element of success as in the foundry business. Hence the difference of success between different individuals where locality and material have been equally favorable. Neither education nor superior means is a guarantee of success. A vigorous application of the reasoning faculty alone will insure success in a close contest of competition.

SCRAP S.

If a poor molder loses his work, he will always swear that the iron was dull or dirty.

If a good molder loses his work, he knows why he lost it, and remedies the evil next time.

If the cupola makes dull iron, or melts badly, the melter will blame it upon the engineer, and swear he had no blast.

If the cupola makes dull iron, or melts slow, the engineer will swear that the melter has packed the stock too closely in the cupola, and that he is giving it more blast than it had last heat.

The melter that melts ten to one, is a fraud.

Never throw a stone at a melter or foreman of a Cincinnati foundry, for you might hit a tuyere inventor.

The patent cupola that will melt a forty-pound hand-

ladle full of iron every six seconds from the time the blast goes on until the bottom is dropped, and give one hundred and twenty men each four hundred pounds of iron out of twenty ton charges, is the best cupola out.

The best tea-kettle molder in the United States works in nine hollow-ware foundries out of every ten; but the Cincinnati foreman that made eighty-four tea-kettles every day for six weeks, and never lost one of them, is the boss of them all.

The melter that always has trouble with his cupola, and always blames the cause of the trouble on some one else, is a fraud.

There is no telling how much fuel or fire-clay a melter uses when he has a pile to go to.

That darn'd old worn-out cupola will be as good as a new one, if you put a new lining into it and keep it up in proper shape.

That molder who made the big cannon that they drew the ball into with a yoke of oxen, and then took the oxen out through the touch-hole—*he is dead*; and any moulder that comes around and represents himself to be the man, is a fraud.

MALLEABLE-IRON CASTINGS.

The term malleable-iron means an iron from which the carbon has been removed by the operation of puddling and boiling, and is a wrought-iron. The term malleable-iron castings means an iron that has been cast into any desired shape, and then malleableized by removing the carbon by a process of annealing, which consists in burning off the whole or a part of the carbon combined with the iron from which the castings were made.

In the manufacture of malleable-iron castings, the first

object is to get the proper kind of pig-iron, for all iron is not suitable for making malleable-iron by the process of annealing. From the states in which carbon exists in cast-iron, this has been classified into three principal sub-divisions. The first is the gray metal, or number one foundry pig, in which the carbon is not combined with the iron, but is in the graphitic state, and may be seen in large flakes when the iron is broken. These flakes are sometimes called tissue and black-lead. The second division is the mottled cast-iron. In this iron the carbon is partly combined with iron and partly in the graphitic state, which gives the iron a spotted or mottled appearance. This iron is also called forge, or mill-iron. The third division is the white cast-iron. In this iron the carbon is combined with the iron, and is unseen. This iron is also called forge, or mill-iron.

The gray iron, or number one foundry-iron, is the best iron for ordinary foundry castings, because it contains the most carbon, and is softer, and will remain fluid longer than either the mottled or white irons; yet it is not the best iron for malleable castings, for the carbon in it is not combined with the iron, and in converting the castings into malleable-iron, the carbon is extracted from the iron without melting the castings, and if this class of iron is used, the castings will be full of small holes after they have been malleableized, and they will not have the required strength.

The iron that will make the best malleable castings is the white cast-iron, for in this iron the carbon is completely combined with the iron, and when it is abstracted from it by the annealing process, it leaves a perfectly sound and smooth casting. But in using this iron for malleable castings, another trouble arises. The iron contains so little carbon that it will not retain its fluidity long enough to be run into light castings; and almost all of the malleable castings are very light, so that this class of iron cannot be used.

And as the gray iron, or number one foundry iron, contains too much carbon, and the white iron too little carbon, the best iron for malleable castings must be the mottled iron, which is between the two extremes. And this is the iron that is always used for malleable-iron castings, and none but the very best brands of cold-blast charcoal mottled iron will produce a good malleable casting. The brands of iron that are considered the best for malleable castings are the Baltimore and Chicago irons. These irons each have their local names, but among the foundrymen they are generally known by the above names. The numbers four and five Baltimore irons are generally used together, as they produce the best castings; and the numbers five and six Chicago irons are generally used together, as they produce the best castings. These irons are graded different, so that the numbers four and five Baltimore irons are the same as the numbers five and six Chicago irons. These irons are not clear white in the pigs, but are slightly mottled, and contain just enough carbon to give the iron the necessary fluidity, while in the castings the iron is a clear white. There are several other brands of iron that are used for malleable castings, but as I have not melted or worked any of them, I cannot give their names, nor the numbers that produce the best castings.

Iron for malleable castings may be melted in a cupola, or in either of the reverberatory furnaces (figures 20 and 21).

But the iron melted in a reverberatory furnace always produces by far the best castings, for the iron is not melted in contact with the fuel, as in the cupola, and it is not deteriorated by the impurities contained in the fuel. There is also the advantage that, should the iron contain too much carbon, part of it may be removed by the oxidizing action of the flame.

As most all malleable castings are very small, they

are generally molded in snap-flasks, with green sand, from metallic patterns, or match-plates. The castings, before they are annealed, are as hard and brittle as glass, and they must be handled with care to prevent breaking. These castings are put into a tumbler, or rattle-barrel, where they are cleaned of all adhering sand, and become polished by mutual friction; and to have them anneal properly, it is very essential that they should be thoroughly cleaned. The cleaned castings intended for conversion into malleable iron are next packed into iron boxes with alternate layers of fine iron scales from rolling-mills. The boxes are then closed at the top by a mixture of sand and clay, and all the cracks are carefully closed up to prevent the admission of air. The boxes are next put into the annealing-oven, where they are subjected to a white heat, not sufficiently hot, however, to melt the boxes. They are kept at this heat for a week or more, and then allowed to cool off gradually. After the castings have been properly annealed, they are covered with a film of oxide of different colors, and resemble in appearance that kind of Champlain iron ore called peacock ore. These various colors of the oxide are a sign of good malleables. This adherent oxide is removed from the casting by another passage through the rattle-barrel, and the process of malleable-iron making is finished.

Powdered iron ore is sometimes used in place of the iron scales, but it is not near so good as the scales, for it contains more or less silica and earth, which, at the temperature of the annealing-oven, will fuse and form a slag, or cinder, and prevent the oxidizing action on the castings. For this reason the scales are to be preferred, and care should always be taken to keep them as free from earthy matter as possible. In every heat or annealing operation, the scales part with some of their oxidizing properties, and before they are again used they must be pickled and re-oxidized. This is

done by wetting them with a solution of sal-ammoniac and water, and mixing and drying them until they are thoroughly rusted, when they are again ready for use. The annealing-boxes were formerly made of soft iron, but at the present time they are mostly made of hard iron, the same as the castings are made of. The hard iron boxes become annealed the same as the castings, and will last longer than the soft iron boxes. These boxes are generally made about twenty inches long by fourteen wide and fourteen deep. They are set one on top of another in the annealing-oven, but are never set more than two high. The lower one has a bottom cast in it, but the top one has no bottom, and is merely a frame set on the lower box. These boxes only last a few heats, and the small boxes are said to last longer than the large ones.

There are several different kinds of annealing-ovens in use at the present time, and some very important improvements have been made in the construction of these ovens in the last few years. The best one in use at the present time is one with a fire on each side of it, and so arranged that the flame from the fuel does not enter the oven or strike the boxes. This oven is not allowed to cool off, but is kept hot all the time, and at one end there is a door through which the annealing-boxes are removed while at a white heat, and are replaced by cold ones. The door is then closed, and the boxes heated to the required heat. This kind of an oven is the most economical one in use, for it requires less fuel than any of the others, and is not injured by expansion and contraction in cooling and re-heating, as the other ovens are. When annealing the castings in the oven, care should be taken to not have the temperature of the oven too high, or the heat too prolonged, or the castings may be burnt and hardened after they have been softened. After the castings have been thoroughly decarbonized by annealing in the oven, they are virtually a

commercially pure iron, and are the same as wrought-iron without fiber, and fiber may be imparted to them by rolling or hammering. Yet these castings without fiber are sometimes equal to the best wrought-iron for strength, and may be bent double when cold without breaking them. The manufacture of malleable-iron by the process of annealing is older than is generally supposed. It appears to have been known in the year 1700, and malleable castings were then made upon the same principle as they now are, although it is doubtful whether the process had been brought to the same perfection in those days as at the present time.

THE FOUNDING OF ALLOYS.

A DESCRIPTION OF THE
SOURCE, PHYSICAL CHARACTER AND USES
OF ALL THE
METALS AND ALLOYS
EMPLOYED IN
THE MECHANICAL AND USEFUL ARTS OF LIFE.

THE FOUNDING OF ALLOYS.

The term *alloy* means a compound of two or more metals, but when one of the metals entering into the compound is mercury, the compound is then termed an *amalgam*. The founding of alloy seems to be older than the founding of iron; for although we read in the Scriptures of iron and brass, yet we do not find any account of the founding of iron, while we do find accounts of the founding of alloys, both in the Scriptures and ancient history. In the description of Solomon's temple, in the Scriptures, we find that all the pillars, chapters, wreaths, panels, bases, and the twelve oxen and the bason or sea that set upon the twelve oxen, were all made of bright brass; and all the vessels for the temple were made in such great abundance, that the weight of them could not be found out; and all these castings for the temple were cast by Hiram, in the plain of Jordan, in the clay ground. From this description it would seem that these castings were made either in green sand or loam, and it is probable that the processes of molding them were the same as the processes of molding in use at the present time. At the time of the building of the temple by Solomon, the Israelites do not seem to have understood the founding of alloys to the same perfection as the other nations around them; for, when about to build the temple, Solomon sent to Hiram, King of Tyre, to send him a man cunning in

the working of brass; and in one part of the Scripture it is recorded that the King of Tyre sent him a man who was a widow's son, of the tribe of Naphtali, and his father was a man of Tyre, and a worker in brass. And in another part of the Scriptures it is recorded that he sent him the son of a woman of the daughters of Dan, and his father was a man of Tyre, skillful to work in gold, silver, brass, iron, etc. Whether the King of Tyre sent Solomon any more men to work in brass, is not stated; but as was customary in those days, Hiram, the King of Tyre, seems to have gotten all the credit for doing the work.

The founding of alloys seems to have been brought to great perfection by almost all of the ancient nations, for all their implements of war, such as the sword, spears, shields, etc., were made of bronze, and all their tools, ornaments, etc., seem to have been made of alloys of different metals. Bright brass seems to have been a favorite metal in the days of Solomon, and it is probable that the ancients valued the bright and showy alloys more than the less showy metal, iron. The alloy bronze seems to have been used by all the ancient nations for weapons, shields, edged tools, etc. The ancients understood the art of hardening and tempering bronze to perfection, so that the want of steel was not so severely felt as we may be inclined to believe at the present time. The ancient Mexicans understood the art of converting bronze into edged instruments, in a high degree. The bronze of the ancient Greeks consisted chiefly of copper and tin, but some of their bronze instruments have been found that also contained gold, silver, lead, zinc and arsenic.

The ancients appear to have been acquainted with only seven metals; at the present time we are acquainted with fifty-one or fifty-two; yet the metals to which the application of useful metals most peculiarly belongs at the present time, were most all known to the an-

cients, although we have fifty-one or fifty-two metals at the present time. Only about fourteen of them are used in the foundry of metals or in the useful arts of life. The majority of these fifty-one or fifty-two metals are merely chemical curiosities of no practical value whatever.

METALS AND RECIPES FOR ALLOYS.

Of all the known metals in use at the present time, iron and platinum are the only metals that bear welding and forging well, and iron or steel is the only metal that admits of being hardened beyond that degree which may be produced by simple mechanical means, such as hammering, rolling, etc. Yet all the metals, with the exception of platinum and its kindred metals, admit of ready fusion; and their fusibility offers an easy means of uniting them, and many of them combine with other metals with great readiness, and by mixing two or more of these metals by means of fusion, an alloy may be formed that is of an entirely different nature from any of its constituents, and by the process of founding alloys, may be cast into any desired form. The malleability and ductility of these metals, as well as their hardness and brittleness, is often increased by alloying with each other, and these qualities are often turned to many useful and varied purposes. The ready fusion of these metals also affords a ready means of uniting two or more metals by the fusion of a third metal, by the process of soldering. Some of these metals will unite with others in almost any proportion, and forms a perfect chemical mixture which, in many cases, produces a superior metal to either of its constituents, while in others the chemical affinity is limited, and they will only unite in certain proportions, and

when mixed beyond these proportions, the alloy is only a mechanical mixture, and often forms an inferior metal to either of its constituents. I have given several recipes for the formation of alloys by mixing these different metals; but in using these or other recipes in forming alloys, the founder must not be guided entirely by the recipe, but he should use his own judgment as well, for the metals may contain certain impurities, or, as it is termed, be a poor metal, which will produce different results; and in order to produce good alloys, a long practical experience is as essential as good recipes; for a man who has not had practical experience in forming alloys, can no more produce a perfect alloy from a recipe than a school-boy can produce perfect writing from his first copy.

ALLOYS OF IRON.

All admixtures added to iron make it more fusible than when pure, although the admixtures added may not be a metal.

Lead can be alloyed with iron in small quantities. A small amount of lead causes iron to be soft and tough, but too much causes it to be extreme cold-short.

Copper, if alloyed with iron, causes it to be extreme red-short, and more than one per cent. of copper will cause it to be cold-short; but a small amount of copper will increase the strength of iron when cold.

Arsenic imparts a beautiful white color to iron, resembling silver, but it makes it very brittle.

Tin, when alloyed with iron, makes a beautiful fine white metal, and when the tin and iron is alloyed about half-and-half, the alloy is as hard as steel; but it cannot be forged.

Chromium, alloyed with iron, makes an alloy that is

as hard as diamond; but it is very difficult to make this alloy.

Silver, alloyed with iron in small quantities, causes the iron to be very hard and brittle, and very liable to corrode.

Gold can be alloyed with iron in any amount. It causes the iron to be more yellow and tough. This alloy is principally used as a solder for small iron castings.

Carbon makes iron more fusible. From one to two per cent. of carbon, added to iron, makes hard cast-iron, and from five to six per cent. makes number one foundry iron. More than five or six per cent. of carbon causes iron to be very brittle, and less than one per cent. of carbon causes iron to be very hard and brittle.

Sulphur causes iron to be both hard and brittle, either when hot or cold, and it causes molten iron to be short-lived. Fuel with sulphur in it should not be used for melting iron in contact with the fuel.

Phosphorus is very injurious to iron. One-half of one per cent. will cause iron to be very hard and brittle when cold, but it imparts a brilliant and white color to iron more perfectly than any other metal.

Silicon makes iron brittle and hard. It has a similar effect on iron to phosphorus, but it is not near so injurious to the iron.

All cast-iron contains more or less carbon, sulphur, phosphorus, and silicon, and as these substances predominate, they form hard or soft, strong or brittle irons; and as all anthracite coal and coke contain more or less of these substances, the anthracite or coke iron is less pure and more variable than the charcoal irons; and on account of the uncertainty of the amount of these impurities contained in cast-iron, it is very difficult to make an alloy of iron and other metals with any certainty as to the result, and for this reason alloyed iron is very little used.

PLATINUM ALLOYS.

Seven parts platinum, sixteen parts copper, and one part zinc, make an alloy that is almost equal to gold.

Ten parts platinum and one part arsenic form an alloy that is fusible at a heat a little above redness. It can be cast into any desired shape, and the arsenic evaporated and the platinum left in its pure state, and infusible.

Two parts platinum, three parts silver, and ten parts copper, make an alloy that is very elastic, and does not lose its elasticity by annealing, and it will bear hammering when red hot, or may be rolled and polished.

Tin is sometimes alloyed with platinum, but the tin increases the fusibility of the platinum, so that the alloy is little better than an alloy of tin and lead.

Platinum is but little used in forming alloys with other metals.

GOLD ALLOYS.

Gold leaf contains from four to ten grains of copper and silver to the ounce of leaf.

The gold plate used by dentists contains about eighty parts gold and twenty parts copper.

Five parts gold and five parts copper make a gold with a reddish cast.

Ten parts gold, four parts copper, and one part silver, make a rich reddish-colored gold.

Eighteen carats gold of a yellow tint is composed of sixty parts gold, eleven parts silver, and nine parts copper.

Eighteen carats gold of a red tint is composed of sixty parts gold, seven parts silver, and thirteen parts copper.

Sixteen carats gold is composed of sixty parts gold,

ten parts silver, and twenty parts copper. This makes a very tough and springy alloy that is sometimes used for springs instead of steel.

Fifteen carats gold of a red tint is composed of ten parts gold, one part silver, and four parts copper.

Fifteen carats gold of a yellow tint is composed of twenty parts gold, seven parts silver, and five parts copper. This makes a very fine alloy that is much used by jewelers.

Gold with a green tint is composed of sixty parts gold and ten and one-half parts silver.

Gold with a gray tint is composed of forty parts gold and fifteen parts silver.

Gold with a blue tint is composed of equal parts of gold and steel filings.

Solder for eighteen carats gold is made of forty-eight parts eighteen-carats gold, four parts silver, and two parts copper.

Solder for twenty-two carats gold is made of forty-eight parts twenty-two carats gold, four parts silver, and two parts copper.

Solder for fifteen carats gold is made of twenty-four parts fifteen-carats gold, ten parts silver, and eight parts copper.

In the above solders yellow brass is sometimes used instead of copper, as it makes the solder more fusible. When copper is used, a little zinc is sometimes added, but it is better to add the zinc in the shape of brass.

SILVER ALLOYS.

Nineteen parts silver and one part copper form an alloy for silver plate.

Fifteen parts silver and four parts copper form a harder alloy than the above. It is also used for silver-plated spoons and trinkets.

The silver coin of the United States is composed of nine parts silver and one part copper.

Silver solder is composed of thirty-three parts silver, fifteen parts copper, and two parts old brass.

Hard silver solder is composed of six parts silver and two parts old brass.

Soft silver solder is composed of four parts silver to two parts old brass. This alloy is the one commonly used for soldering silver. Some add a little arsenic to it to make it more fusible and white, but when arsenic is added care should be taken to avoid its fumes, both when making the solder and when using it. The old brass is used in these alloys to avoid wasting the zinc.

Silver is sometimes soldered with the common solder used for soldering tin, but it will not receive a polish, and a nice job cannot be made with it.

The alloys of silver are but little used in founding, for they all expand at the moment of solidification, if they contain much silver.

GERMAN SILVER ALLOYS.

German silver is composed of eighty parts copper, twenty parts nickel, and thirty-three and one-half parts zinc.

The best quality of German silver is composed of one hundred parts copper, fifty parts nickel, and fifty parts zinc.

The white copper, or packfong of the Chinese, which is the same as the German silver of the present day, is composed of forty-one parts copper, seventeen parts nickel, thirteen parts zinc, and two and one-half parts iron.

A very hard German silver is made of eight parts

copper, four parts zinc, two parts nickel, and one part iron. This alloy is very tenacious and ductile.

A still harder German silver is made of sixteen parts copper, eight parts zinc, four parts nickel, and three parts iron.

The finest quality of German silver that is made is composed of sixteen parts copper, eight parts nickel, and seven parts zinc.

Ten parts copper shavings and four parts arsenic, arranged in a crucible in alternate layers, and covered with a layer of common salt, make a beautiful white alloy that is almost equal to silver. In making this alloy care must be taken to avoid the fumes of the arsenic.

BISMUTH ALLOYS.

Fifty parts bismuth, twenty-five parts lead, and twenty-five parts tin, form a very fusible alloy, which melts at 200° Fahrenheit.

Fifty parts bismuth, thirty parts lead, and twenty parts tin, form a still more fusible alloy, which melts at 190° Fahrenheit.

Eight parts bismuth, three parts lead, and two parts tin, form an alloy that melts at 212° Fahrenheit.

Eighty parts bismuth, fifty parts lead, forty parts tin, and ten parts type-metal, constitute a harder but less fusible alloy than any of the above mixtures.

Soft solders and pewters are made of four parts bismuth, eight parts lead, and six parts tin; or two parts bismuth, two parts lead, and four parts tin.

All the above alloys must be cooled quickly to avoid the separation of the metals. In order to get the metals thoroughly mixed, they should be repeatedly melted and poured into drops.

BRASS ALLOYS.

A very good brass is made of sixteen pounds of copper, eight pounds of zinc, and one-half pound of lead. The lead should be added after the copper and zinc have been melted together. These proportions of the different metals make the best brass that can be made with zinc and copper. For very light castings the lead should be omitted, as it makes the alloy less fluid ; but in heavy castings, it makes them more solid and clean.

Button-brass consists of twenty-four parts copper to fifteen parts zinc.

Red-brass is made of nine parts copper and one part zinc.

Red-brass made at Hegermuhl consists of five and one-half parts copper and one part zinc.

Brass that bears soldering well consists of sixteen parts copper and six parts zinc.

Brass for ship-nails consists of twenty parts copper, sixteen parts zinc, and two parts iron.

Red sheet-brass is made of nine parts copper and two parts zinc.

Brass for sheathing, bolts, fastenings, etc., is composed of six parts copper and four parts zinc. This composition forms an alloy that may be rolled and worked at a red heat.

Brass for pumps, and machinery requiring great tenacity, is made of thirty-two pounds copper, three pounds tin, and one pound zinc.

Brass for gear-wheels, to have teeth cut in them, is made of thirty-two pounds copper, three pounds tin, and two pounds old brass. If it is desirable to have the wheels harder, a little more tin may be added.

An alloy for turned and finished work is made of thirty-two pounds copper, four pounds tin, and three pounds old brass. For nuts of coarse thread, one-half pound more tin may be added.

As more tin is added to alloys of copper and zinc, or copper and old brass, the alloy becomes harder. Razors have been made of an alloy of thirty-two parts copper, five parts tin, and five parts zinc.

The best white hard metal for buttons is made of sixteen parts copper, two parts zinc, and one part tin.

LEAD AND COPPER ALLOYS.

Seven parts lead and sixteen parts copper makes a very cheap alloy, but it is rather short, and easily broken.

Two parts lead and eight parts copper makes a red-colored alloy that is very tough.

A red-colored and ductile brass is made of two parts lead and sixteen parts copper.

Ordinary pot-metal is made of six parts lead and sixteen parts copper. This alloy is very brittle when hot, but tough when cold. The alloys of copper and lead are all very brittle when hot. More than one-half pound of lead cannot be alloyed with one pound of copper, for the copper will not unite with the lead, and the lead will ooze out in cooling. Alloys of lead and copper are very little used.

Lead and copper alloys have a bluish, leaden hue when much lead is used, and are principally used on account of their cheapness.

BRONZE ALLOYS.

A bronze in imitation of gold may be made of 45.5 parts copper, 3.5 parts tin, and one part zinc—fifty parts.

Bronze medals are generally cast of an alloy of fifty

parts copper and 2.8 parts tin. This alloy is very hard.

A softer bronze for medals than the above is composed of forty-six parts copper and four parts tin.

Ancient bronze nails were made of forty parts copper to one part tin, and were very flexible.

Soft bronze is composed of eighteen pounds copper to two pounds tin.

Hard bronze is composed of twenty pounds copper to five pounds tin.

The ancient bronze mirrors are said to have contained sixteen parts copper to from seven to eight parts tin.

At the time of Louis XIV of France, a period when the art of casting statues was much cultivated in France, statues were cast of an alloy of 30.6 parts copper, 0.11 parts tin, two parts zinc, and 0.6 parts lead.

The statue of Louis XV is cast of 82.4 parts copper, 10.3 parts zinc, four parts tin, and 3.2 parts lead.

The bronze of the ancient Greeks consisted chiefly of copper and tin, but was frequently alloyed with arsenic, zinc, gold, silver and lead. All their shields and weapons of war were made of bronze, as well as coin, nails, kitchen utensils, etc.

All the ancient nations seem to have understood the art of tempering bronze and copper, and the ancient Mexicans understood the art of converting bronze into edged instruments in a high degree, but the art of tempering and hardening bronze and copper has been lost to modern nations; but as we understand the working of iron better than the ancients, and have steel, an alloy of iron and carbon, which the ancients did not have, we do not miss this art much.

BELL-METAL ALLOYS.

One hundred and forty-four pounds copper, fifty-three pounds tin, and three pound iron, is said to make a superior bell. Iron, copper and tin do not unite well, if each is added separately to the other, but if tin-plate scraps are melted in a crucible together with tin, and then this tin and iron alloy added to the molten copper, it will unite readily.

Another alloy that is highly recommended is composed of 53.5 parts copper, 6.11 parts tin, 2.13 parts lead, and 3.9 parts tin. This alloy has a good, sonorous sound, even if the mold is not thoroughly dry.

House bells are made of four pounds tin to sixteen pounds copper.

Soft musical bells are made of three pounds tin to sixteen pounds copper.

Common bell metal consists of fifty pounds copper to fifteen or twenty pounds tin.

The silver bells of Rouen, France, consist of forty pounds copper, five pounds tin, three pounds zinc, and two pounds lead.

Too much tin causes bell metal to be brittle.

The gongs or cymbals and tam-tams of the Chinese are composed of forty pounds copper to ten pounds tin. To give these musical instruments their proper tone, they are plunged in cold water while hot, after being cast; cooling in water deprives the metal of almost all its sound. It is tempered and very slowly cooled, which imparts to it that peculiarly powerful sound.

If bell metal is suddenly cooled, it becomes less dense and hard, and is increased in malleability; but the tone of the metal is decidedly impaired, and bells ought never to be cast in damp molds. When bells are cooled suddenly they should be re-heated and tempered by cooling slowly.

TYPE - METAL.

Six parts lead and two parts antimony form a very hard and brittle alloy used for small type.

Eight parts lead and two parts antimony form a softer alloy that is used for larger type.

Ten parts lead and two parts antimony form an alloy that is still softer, and is used for medium-sized type.

Fourteen parts lead and two parts antimony form an alloy that is softer than any of the above alloys, and is used for the largest sized type.

A small amount of tin is sometimes added to the above mixtures, and some type-founders add one or two per cent. of copper. Both of these metals improve the quality of the type, when used in small quantities.

Forty parts lead, eight parts antimony, and two parts tin, form an alloy that is used for stereotype plates.

Six parts lead and two parts tin form coarse solder, used by plumbers. This alloy melts at about 500° Fahrenheit.

Two parts lead and four parts tin form the fine solder used by tinnern. It melts at about 350° Fahrenheit.

LEAD ALLOYS.

Ninety-four parts lead and six parts antimony form an alloy that may be rolled into sheets, and is a little harder than pure lead. This alloy is much used for sheathing for ships.

Twenty-four parts lead and four parts antimony form an alloy that is used in place of babbitt metal for filling small boxes and bearings.

Twenty parts lead and four parts antimony form an alloy that is a little softer than the above, and is used for the same purpose. Either of these may be hardened by the addition of more antimony; but care must be taken to not use too much antimony, for it will cause the alloy to lose its fluidity, and it cannot be run into the boxes.

All alloys of lead and antimony are rendered more fluid by melting them under a covering of oil.

Five parts lead and five parts tin make a beautiful white alloy, used for organ pipes. The mottled, or crystalline appearance, so much admired in the pipe, is caused by using an abundance of tin.

One hundred parts lead and two parts arsenic form an alloy from which drop-shot is made.

Eighteen parts lead, four parts antimony, and one part bismuth, form an alloy that expands on cooling. This alloy is much used for metallic patterns for snap-moldings.

SPELTER-SOLDER ALLOYS.

A good solder for copper and iron is composed of three parts zinc and four parts copper.

A softer solder that is used for ordinary brass work is composed of equal parts of zinc and copper.

A very hard but fusible solder is composed of two parts zinc and one part copper. This solder is so hard and brittle that it can be easily crumbled in a mortar when cold.

The two first solders are first alloyed and cast into ingots. The ingots are allowed to cool in the mold and then re-heated nearly to redness upon a charcoal fire, and are broken up on the anvil, or in a mortar, into a finely granulated state, for use.

HARD-SOLDER ALLOYS.

The following metals and alloys are usually used as solder in the art of hard-soldering :

Fine or pure gold, rolled or beaten into sheets, and cut into shreds, or small pieces, is used as the solder for soldering chemical vessels made of platinum.

Silver solder, composed of four parts silver and two parts yellow brass, is much used for hard soldering. The brass is used in this solder, so that the operator can tell when the solder is fused, by seeing the blue blaze caused by the burning of the zinc. This solder is either rolled into thin sheets, and cut into small bits for use, or is granulated while hot.

The gold solder, the composition of which is given under the head of gold alloys, is rolled into thin sheets and used for soldering gold alloys. Gold soldering is generally done with the blow-pipe, as the work is seldom large enough to require the brazier's hearth.

Pure copper, in shreds, is sometimes used for soldering iron.

Spelter-solders, granulated while hot, are used for soldering iron, copper, brass, gun-metal, German-silver, and sometimes for gold and silver alloys.

As a cheap substitute for silver solder, the white, or button-solders are commonly employed for the white alloys, such as German-silver, gun-metal, etc.

The flux most generally used in hard-soldering is borax. In fact, there is very little hard-soldering done without the aid of this flux. It is generally granulated, and used in the dry state for large or heavy work, and for small work it is generally used in solution with water.

SOFT-SOLDER ALLOYS.

The soft solder used by plumbers, called sealed solder, is composed of two parts tin and four parts lead. This solder melts at about 450° Fahrenheit.

The common solder used by tinsmiths is composed of four parts tin and two parts lead. This solder melts at about 350° Fahrenheit.

The bismuth solder is composed of seven parts bismuth, five parts lead, and three parts tin. This solder melts at about 225° Fahrenheit.

All the tin and lead solders become more fusible the more tin they contain. Thus, one part tin and ten parts lead melt at about 550° Fahrenheit, while six parts tin and one part lead melt at about 375° Fahrenheit; and all the tin, lead and bismuth solders become more fusible the more lead and bismuth they contain.

The fluxes used in soft soldering are: borax, sal-ammonia, chloride of zinc, common resin, Venice turpentine, tallow, and sweet oil. Those most commonly used for ordinary work, are: common resin and chloride of zinc.

BABBIT ANTI-FRICTION
METAL.

This metal is made of one part copper, three parts tin, two parts antimony, and three parts more tin are added after the composition is in the molten state. This composition is called hardening, and when the metal is used for filling boxes, two parts tin are used to one of hardening. The above alloy constitutes the best anti-attrition metal in use, but on account of its expense it is very little used. The anti-attrition metals commonly used are principally composed of lead, antimony and a little tin, but they are not near so good as the above

FLUXES FOR ALLOYS.

The best flux for alloys of copper and tin is rosin. It should be added when the metals are almost melted.

Another good flux is sal-ammonia. In using this flux the copper is usually melted first and the flux added. When it is in the mushy state, after the flux has been put in, the zinc and tin are then added.

A good flux for old brass is common rosin-soap. It should be added in small lumps and stirred down into the metal when in the molten state.

In forming alloys of different metals, the molten metals should always be kept under a covering of black glass or pulverized charcoal, to prevent oxidation.

BLACK FLUX.

Black flux, as it is commonly called, is composed of seven parts of crude tartar, six parts of saltpetre, two parts of common bottle glass, and by some a small amount of calcined borax is added. These ingredients are first finely pounded and mixed together, and then gradually heated in an iron pot or ladle so as to burn them together. Care should be taken to not overheat the mixture; and as soon as it is thoroughly melted and mixed together, it should be removed from the fire and allowed to cool. After it has cooled it is finely pulverized and sifted, and is then ready for use. It has a great affinity for moisture, and should be protected against it by being placed in glass bottles and the bottles corked up until wanted for use. This is the most powerful flux that can be made. It is but little used in forming or fluxing alloys, but it is principally used by assayers in assaying of different kinds of metallic ores. In these assays the quantity of black flux used

varies according to the quality of the ores, but the amount generally used is about an equal amount of ore and flux. The ore is first roasted and then finely broken up and mixed with the flux, and the whole is then rapidly heated in a crucible. If the flux does not make the slag sufficiently fluid to allow the metal to settle, a small amount of calcined borax is added, which makes the slag more liquid and permits the metal to pass to the bottom of the crucible. The crucible is then removed from the fire and the mixture either poured from it or allowed to cool in it. After it has cooled, the slag is knocked off with a hammer and a button of metal obtained. When using this flux the clay crucible, without either coal or plumbago, is preferred, for the flux is very hard on a crucible that contains either of these substances. Black flux is used by some foundrymen in melting the fine scrap sweepings from the floor, and dross and refuse from the crucibles, by melting these in a crucible with black flux. They obtain considerable amounts of metal from them that would otherwise be lost. In melting this refuse with black flux, the common clay crucible should always be used.

NATURE AND CHARACTER OF ALLOYS.

Alloys of gold, silver and copper are generally superior in strength to any of the more fusible metals, and may be forged either when red hot or cold. These three metals seem to unite in any proportions, and always form an alloy that is malleable when either hot or cold.

Pure gold is but little used in the arts; it is then too soft. It is generally alloyed with silver and copper, both to harden it and depreciate its value. Alloyed

with copper, it forms gold of a red tint; with silver, it forms gold of a green tint; and alloyed with both copper and silver, it gives intermediate tints.

Pure silver is but little used alone; it is generally alloyed with a small amount of copper, which does not change its color, and greatly improves its malleability and working qualities.

When gold, silver or copper are alloyed with the more fusible metals—lead, tin and zinc—the alloy is less malleable and ductile than alloys of gold, silver and copper. They are extreme red-short, and when heated to redness they will fly to pieces under the hammer; and alloys of brass, bell metal, etc., must be treated with precaution, and should never be taken out of the mold while red hot.

Alloys of two parts copper and one part zinc are very soft and malleable, and may be drawn by hammering, or easily cut with a file; but an alloy of one part copper and two parts zinc is as hard and brittle as glass, and may be easily pulverized.

An alloy of two parts copper and one part lead makes a soft, malleable metal, but is inferior to an alloy of copper and zinc. In alloys of one part copper and one part lead, the lead will ooze out in cooling. In alloys of one part copper and two parts lead, the lead will not unite, but will sink to the bottom when cooling.

Alloys of six parts copper and one part tin make a very hard alloy, and the alloy gets harder and whiter the more tin is added. Alloys of tin and copper should not be too rapidly exposed to the air, for if a large percentage of tin is used, it will strike to the surface and ooze out, or make hard spots in the casting.

Alloys of zinc and lead cannot be made without the addition of arsenic, unless the lead is alloyed in a very small quantity.

Alloys of zinc and tin are very hard and brittle, and are but little used alone. By the addition of copper to

alloys of these two metals, the alloy is rendered more malleable and soft.

Arsenic makes all alloys hard and brittle, and is very dangerous to use. It is seldom used except to impart fluidity to the very infusible metals.

Alloys of lead and tin are very malleable and ductile when cold, but at a temperature of about 200° Fahrenheit, they lose the power of cohesion and are exceedingly brittle. The alloys of tin and lead partake of the general nature of these two metals. They are soft and malleable when cold, even when a small amount of brittle antimony has been added.

An alloy of six parts lead and one part antimony is very soft and malleable, but an alloy of three parts lead and one part antimony is very hard and brittle; and an alloy of one part lead and one part antimony is harder and more brittle than antimony.

FUSIBILITY OF ALLOYS.

In forming alloys of the different metals, they do not combine with each other in their solid state (with the exception of mercury), owing to their chemical affinity being counteracted by the force of cohesion; and in order to form combinations of them, it is necessary to liquify at least one of them, in which case they will unite, provided they have a chemical affinity for each other; thus bell metal and brass is formed, when pieces of tin, or zinc, are put into molten copper; and in the formation of alloys, of this nature, where one of the metals are more fusible than the other, the less fusible metal should be fused first, and the more fusible metals added either in the molten or solid state. As the fusible metals are added, the temperature of the alloy should be reduced, to prevent oxidation, or burning

away of the fusible metals; for this reason, it is better to add the more fusible metals in the solid state, as by so doing the temperature of the metals is decreased. Alloys are always more fusible than the less fusible metals, of which they are composed, and in some cases are more fusible than the most fusible metal they contain, as is the case in alloys of tin, lead and bismuth. Some founders, in order to have the metal thoroughly united, first fuse the metals together, and cast them into ingots and re-melt them for use; this practice is bad, for in the after-fusion there is always more or less of the more fusible metal burnt away, and it is hard to determine the proportions of the alloy, or to have any certainty as to the quality of the castings. In melting ingots, or scrap alloys, they should be fused as rapidly as possible, and at the lowest available temperature, so as to avoid oxidation.

Some of the metals are almost infusible; and when heated to the highest heat, in a crucible, they refuse to melt and become fluid; but any of the metals can be melted, by combination with the more fusible metals; thus, platinum, which is infusible with any ordinary heat, can be fused readily, when combined with zinc, tin or arsenic; this metal, by combination with arsenic, is rendered so fluid that it may be cast into any desired shape, and the arsenic may then be evaporated by a mild heat, and leave the platinum, in its pure state, cast into any desired shape. Nickel, which barely fuses alone, will enter into combination with copper, forming German silver, an alloy that is more fusible than nickel and less fusible than copper; this alloy is rendered the whiter, harder and less fusible the more nickel is added. The less fusible metals, when fused in contact with the more fusible metals, seem to dissolve in the fusible metals: rather than melt the surface of the metal, is gradually washed down, until the entire mass is dissolved or liquified, and reduced to the state of alloys.

In forming alloys of brass, in furnaces where heat enough cannot be obtained to fuse the copper separately, the alloy may be formed by heating the copper to the highest heat, and then adding the zinc or tin, in the molten state, so as not to reduce the temperature of the copper.

In forming alloys with new metals, it is usual to melt the less fusible metals first, and then add the more fusible metals, and mix them by stirring them well together; the rod used in stirring them should be heated to redness, to prevent lowering the temperature or chilling the metal. In mixing alloys for bells, the alloy should be well stirred with an iron rod, well heated, in which case part of the iron is dissolved, and combines with the alloy, and gives the bell a better tone; but alloys of brass, that are to be turned, or finished, should never be stirred with an iron rod, for the iron dissolved from the rod will cause hard specks in the alloy if not thoroughly mixed. In forming fine alloys, the alloy should be stirred with a rod of the least fusible metal contained in the alloy, or with a wood stick; the wood stick, in many cases, is better than a metallic rod, for it causes the metal to boil slightly, and unite more thoroughly; but the wood stick cannot be used in a small crucible, with only a small amount of metal. When alloys are made that contain only a very small quantity of a metal that is difficult to fuse, as in pewter, it is scarcely possible to throw into the melted tin the half per cent of melted copper, with any certainty of the two metals being properly combined; and in forming this alloy, it is customary to melt the copper in a crucible and then add to it two or three times its weight of melted tin; this dilutes the copper and makes an alloy, called temper or hardening. This alloy is very fusible and is melted in an iron ladle, and is added to molten tin, or lead, to give it the desired hardness, and form pewter.

The metal mercury will bring about triple combinations of metals, even when the metals have no chemical affinity for each other, either when the metals are melted, or in the solid state, as in water-gilding, where the silver, copper, or metal intended to be gilded is first made chemically clean by washing in acids and water, and then rubbed over with an amalgam of gold containing about eight parts of mercury. This amalgam immediately attaches itself to the metal, and it is only necessary to evaporate the mercury, which only requires a very low heat, and the gold is left firmly attached to the metal; and it is only necessary to brighten it by burnishing. Water-silvering is accomplished in the same way, and iron or copper, and many other metals, may be tinned in the same way. An amalgam of tin and mercury is made so as to be soft and easily crumbled. The metal to be tinned is cleaned in the same way as in gilding with gold, or by turning or filing, and the amalgam is then rubbed on and the mercury evaporated by heat. This process of tinning is called cold-tinning. Other pieces of metal can be attached to a metal that has been tinned in this way, by soldering.

In the manufacture of tin-plate, the iron plate to be tinned is first scoured and made chemically clean. It is then immersed in a bath of pure molten tin, covered with resin and tallow to prevent oxidation. The iron plate remains in this bath for a short time, and the tin unites, or becomes alloyed with the surface of the plate, and comes out of the bath perfectly coated with tin, and is called tin-plate. In this process the iron plate must be heated to the temperature of the molten tin before combination takes place. But by the aid of mercury the iron plate may be tinned at the atmospheric temperature.

BRASS FURNACES.

Furnaces for the melting of brass and similar alloys may be built of common brick and lined with fire-brick; but the best furnaces for this purpose are made with a boiler-plate caisson from twenty to thirty inches in diameter, and thirty or forty inches high. This caisson is usually set down in a pit, with the top of it only ten or twelve inches above the foundry floor. The ash-pit, or opening around the furnace, is covered with a loose wooden grating, which may be removed for taking out the ashes. The iron caisson is lined with fire-brick, the same as a cupola. The lining is usually six inches or more in thickness. The diameter of the furnace on the inside should not be more than four or five inches larger than the diameter of the crucible intended to be used in it; for if the furnace is too large, more fuel and more time will be required to melt the metal. These furnaces are liable to burn out hollow around where the crucible sets, and to avoid a waste of fuel, they should be straightened up with fire-clay and fire-sand, and always kept as near straight as possible. These furnaces are sometimes built square on the inside, but the square furnaces are not near so good, and require more fuel than the round ones do. A good brass foundry usually has three or more of these furnaces. They are generally of different diameters to suit different sized crucibles, and when it is desirable to make a large casting, that requires more metal than can be melted in one crucible, two or more furnaces are used to melt the metal. But when more metal is required for a casting than can be melted in three or four crucibles, the metal is then melted in the reverberatory furnace, or in the common iron foundry cupola. When melting brass in a cupola, the copper is usually charged and melted before charging the zinc or more fusible

metals, and in some cases the zinc or tin is not put into the cupola at all, but is melted in an iron ladle and added to the copper after it has been drawn out of the cupola. When the amount of brass to be melted in a cupola is small, and the cupola has a good draft, the metal is usually melted without a blast; but when the metal amounts to several tons, a blast is generally used. The swivel cupola (Fig. 16) is well adapted to the melting of brass, and is often used for that purpose. The common brass furnace usually depends upon a natural draft, and the furnace is connected with the stack by a small flue on the back side of the furnace, near the top. Three or more furnaces are usually connected with one stack, and each furnace is supplied with a separate damper for regulating the heat. When the stack is not high enough to give the furnace a good strong draft, the ash-pit is closed up tight, and a mild blast turned into the pit; for better melting can be done by turning the blast into the pit and allowing it to find its way up through the grates, than by putting the blast directly into the furnace by means of tuyeres.

These small brass furnaces are of easy construction; but as a temporary expedient almost any close fire may be used, including some of the common heating stoves, although it is much more convenient that the fire be open at the top, so that the contents of the crucible may be seen without removing it from the fire. Such stoves, however, radiate heat in a somewhat inconvenient manner, and to a much greater extent than the common brass furnace, which is lined with fire-brick or clay, and the lining concentrates the heat and economizes the fuel. The brass furnace is often used for melting iron in a crucible, and they answer equally as well for melting iron as for brass, when the furnace has a good draft. Small amounts of brass are frequently melted in the ordinary blacksmith's fire; but there is considerable risk of cracking the crucible at the point exposed

to the blast. A wrought-iron pot is sometimes used for melting small amounts of brass, but it is not very enduring, for the brass will soon cause it to burn into holes and leak. The fuel used in the brass furnace is generally hard coal or coke, which is broken into lumps about the size of hens' eggs for use. Either of these fuels will do good melting, but the coke will generate heat faster than the coal, and will do faster melting, which will prevent the oxidizing of the metal; and for this reason the coke is to be preferred when it can be obtained. Gas-house coke made from cannel coal is not fit for fuel in the brass furnace.

The fusible metals, or those not requiring a red-heat, such as lead, tin, zinc, etc., are generally melted in a cast-iron ladle or pot. When the metals are melted in large quantities for small work, such as type-founding, the pot is usually set in brick-work, with a fire-place and ash-pit beneath it. In this pot the metal is kept in the molten state all the time, and dipped out with a small hand-ladle for use. When it is only desirable to melt a small quantity of metal, it is usually melted in the small hand-ladle, or in the ordinary plumber's pot over an open fire.

CRUCIBLES.

The word crucible is derived from the word *crux*, a cross; it is said that before the discovery of the gases, that explosions, strange noises and lurid flames had been seen in mines, caverns, etc., and the alchemists whose earthen vessels often exploded with terrific violence, commenced their experiments with prayer, and placed on their crucibles the sign of the cross; hence the name crucible, from *crux*, or *crucis*, a cross.

All the metals, and alloys of metals, with the exception of iron, and the very fusible metals, are melted in

crucibles. There are several different kinds of crucibles; the principal ones in use are, the Hessian pots, the English brown or clay pots, the Cornish and the Wedgewood crucibles, all extensively used for melting alloys of brass, bell-metal, gun-metal, etc., but they are very brittle, and seldom stand more than one heat, yet they are generally sold cheap, and some founders prefer to use a crucible only once, as they think it more safe, for crucibles often crack or burn through on the second heat. The best crucibles, for all kinds of alloys, are the Black-Lead crucibles; these crucibles are sold higher than any of the clay crucibles, but they are more refractory than the clay crucibles, and may be used for three or more successive heats, without any danger of their cracking or burning through. They are not so open and porous as the clay crucibles, and do not absorb so much of the metal, and for this reason they are to be preferred for melting valuable metals. When about to use a crucible, it should be heated gradually, by putting it in the furnace when the fire is started, or by setting it on top of the tyle, or covering of the furnace, with the mouth down; it should be heated in this way until it is almost too hot to hold in the hands. Before it is put into the hot furnace, some founders always stand a fire-brick on its end, in the bottom of the furnace, to set the crucible on, this prevents the crucible from settling with the fuel as it is burnt away. This way of supporting the crucible is a good idea, when the furnace has a poor draft, and the metal is melted slow, and it is necessary to replenish the fuel before the metal can be melted; but in furnaces where the metal is melted quick, and it is not necessary to replenish the fuel in the middle of the heat, the crucible should be allowed to settle with the fuel, as the heat will then be more concentrated upon it. After the metal has been poured from the crucible into the mold, or ingot, the crucible should always be returned to the furnace and allowed to cool

off with the furnace to prevent it from cracking. In forming alloys of brass, etc., a cover or lid for the crucible is seldom used, but a covering of charcoal, or some kind of flux is generally used for the metal. The metal to be melted in the crucible is generally packed into the crucible before it is put into the furnace; and when it is desirable to put in more metal, after the metal has been fused, it is put in with the tongs, if the metal is in large pieces; but when the metal to be added is in small pieces, it is put into the crucible through a long funnel-shaped pipe; the small end of this pipe is used for putting metals into the crucible, and the large end is used for covering the crucible, to prevent the small pieces of fuel from falling into the crucible. When putting fresh fuel into the furnace, after a crucible has been charged with metal, a few pieces of large coke should always be laid on top of it, so as to concentrate the heat upon the metal. Crucibles of all sizes can be obtained from the manufacturers, and small ones can generally be obtained at any drug store; but where it is impossible to purchase crucibles, the founder often has to manufacture them, as I have had to do on several occasions, when making assays of different minerals, in parts of the country where it was impossible to obtain crucibles. In making a crucible, the first thing necessary is to procure a white, tenaceous, plastic clay, which will stand the fire without melting; a good fire-clay, mixed with about one-half coarse sand, will make a good crucible, but where fire-clay cannot be obtained, we must use some other clay, which should be mixed with some old fire-brick finely broken up; and if they cannot be obtained, then pieces of porcelain, Chinese ware, or common stoneware, may be broken up and used with the common clay. If none of these articles can be obtained, then quartz rock, or sandstone may be used. They should be heated to redness, and suddenly cooled by

throwing into cold water, after which they are broken up into a coarse sand and mixed with just enough clay to make it adhere together. Too small a per cent. of clay has a tendency to weaken the crucible, and too large a quantity makes it liable to crack when heated. The mixture of sand and clay must be well worked with the hands before molding it into the crucible. When forming the crucible a wood block of the desired shape may be used for a pattern, and the crucible formed by coating the mixture on to the block and allowing it to get partially dry before removing the block. When it is desirable to make small crucibles, a good-shaped glass tumbler may be used for a pattern, and the mixture coated either on the inside or outside of it, so as to make the sized crucible desired. To prevent the mixture from sticking to the pattern, the pattern may be covered with paper before applying the mixture. The bottom of the crucible should always be a little thicker than the sides. When a crucible has been formed it should be allowed a few days to dry in the sun or in a gentle heat, as it takes some time for the water to evaporate from the clay. When the crucible has been sufficiently dried it is then baked or exposed to a strong red heat. The baking may be done in a common cook-stove oven or in an open fire. When baked in an open fire the crucible should be set in the centre of the fire, and the fuel, either wood or coal, piled all around it, so as to heat it evenly and prevent breakage. After it is sufficiently baked it should be covered over with the hot ashes to protect it from the sudden rush of cold air which will follow the exhaustion of the fire. If it is desirable to have a cover for the crucible, some small slabs may be made of clay and burnt with the crucible.

C U P E L .

The cupel is a small flat cup resembling the bottom of a crucible. It is generally from two to four inches in diameter, and from a half inch to an inch and a half deep, with a flat bottom. It is generally used for refining gold and silver, and is sometimes used by jewelers in forming alloys and melting metals. The cupel is made of finely pulverized bone-ashes and wood-ashes mixed together. In forming the cupel the white bone and wood-ashes must be well pulverized and sifted, and only as much water mixed with them as will cause them to adhere slightly. Care must be taken to not use too much or too little water, for extremes either way are equally injurious. The ashes should be pressed into the desired shape, and a strong pressure brought to bear upon them to unite them properly. The fresh cupels are then air-dried, which may be done in the sun or on top of a stove. After they are thoroughly dried they are ready for use. Without baking or burning, the cupel is easily broken, and requires gentle handling.

B L O W - P I P E .

The blow-pipe and an alcohol lamp are largely used in hard soldering, tempering small tools, and by chemists and mineralogists as an important means of analysis, etc., and for these uses the blow-pipe has received very great attention, both from mechanics and distinguished philosophers. Most of the small blow-pipes are supplied with air from the lungs of the operator, and the larger ones, or where the blow-pipe is brought into general use, it is supplied with air from a bellows moved with the foot, or from a vessel in which the air has been condensed by a syringe, or from a small rotary

fan. The ordinary blow-pipe is a light brass or tin tube about ten or twelve inches long, and from one-half to one-fourth of an inch in diameter at the end for the mouth, and one-sixteenth or less at the jet end. The small end is slightly curved, so that the flame may be thrown immediately under the observation of the operator. There are several other kinds of blow-pipes for the mouth, which are fitted with various contrivances, such as a series of apertures of different diameters, joints for portability and for placing the jet at different angles, and with a ball for collecting the condensed vapor from the lungs; but none of these are in common use. The blow-pipe may be supplied with air from the lungs with much more effect than might be expected, and with a little practice a constant stream can be maintained for several minutes, if the cheeks of the operator are kept fully distended with wind, so that their elasticity alone will serve to impel a part of the air, while the ordinary breathing is carried on through the nostrils for a fresh supply.

The heat created by the blow-pipe is so intense that fragments of almost all the metals may be melted when they are supported upon charcoal, with the heat from a common tallow or wax candle. The most intense heat from the blow-pipe is the pointed flame, and the hottest part of the flame is the extreme point of the inner, or blue flame. Large particles of ore or metals that require less heat, are held somewhat nearer to the candle or lamp, so as to receive a greater portion of the flame, and when a very mild degree of heat is wanted on a small piece of metal, it is held further away. By thus increasing or decreasing the distance between the candle or lamp and the object to be melted, any desirable degree of heat may be obtained. When only a minute portion of metal is to be heated, the pointed flame is used with a mild blast; but when it is desirable to heat a large surface of metal, as in soldering and brazing, a

much larger flame is used. This is produced by using a lamp with a large wick, plentifully supplied with oil, which produces a large flame. The blow-pipe used has a larger opening than the one used for the pointed flame, and it is held a little distance from the flame, and blown vigorously, so as to spread it out over a large surface of the work. This is called the bush, or sheet flame. The work to be brazed or soldered by this flame is generally supported upon charcoal.

When melting metals with the blow-pipe, the metal to be melted is laid upon a flat piece of charcoal, which has previously been scooped out slightly hollow in the center, to prevent the metal from running off when melted. If it is desirable to run the metal into a mold when melted, a small groove, or lip, is cut in the charcoal, and when the metal is sufficiently heated it is poured into the mold. In this way the jewelers melt most all their gold, silver, etc., when making rings and other jewelry. The cupel is also used for melting metals in with the blow-pipe, but it is not so good as the charcoal, for it is liable to break from being heated unevenly, and spill the metals. There are several different kinds of stationary or bench blow-pipes used by jewelers, braziers, etc.; but as the blow-pipe is but little used in the art of founding, I shall not describe them in this work.

BRAZIER'S HEARTH.

In soldering or brazing large work of copper, silver, etc., an open fire is used, called the brazier's hearth. For large and long work, this hearth is made with a flat iron plate about four feet by three, which is supported by four legs, and stands on the floor a sufficient distance out from the wall so that the operator can get all around it. In the center of this plate there is a de-

pression about six inches deep and about two feet long by one wide, for containing the fuel and fire. The fire is depressed in this way so that the surface of the plate may serve for the support of large work, such as long tubes, large plates, etc. The rotary fan is commonly used for the blast. The tuyere iron used is similar to those used for the common blacksmith's forge, but with a larger opening for admitting the blast to the fire. The nasal, or top of this tuyere iron, is fitted loosely into grooves, so as to admit of easy renewal, as they are burnt out in a very short time, and must be replaced to do good work. The fire is sometimes used the full length of the hearth, in which case a long or continuous tuyere is used. Occasionally two separate fires are used on the same hearth. In this case they are separated by a loose iron plate. The hood, or mouth of the stack, is suspended from the ceiling over the hearth with counterpoise weights, so that it may be raised or lowered, according to the magnitude of the work. The common blacksmith's forge fire is frequently used for brazing. It is temporarily converted into a brazier's hearth by being built hollow around the fire, and the fire removed from the wall or flue, out into the center of the hearth. But the brazing operation injures the fuel so that it cannot be again used for ordinary forging of iron or steel. For want of either the brazier's hearth or the blacksmith's forge, the ordinary grate may be used, or it is better to employ a brazier or chafing dish containing charcoal, and the fire urged with a hand-bellows, which should be blown by an assistant, so that the operator may have both hands at liberty to manage the work and fuel. The best fuel for brazing is charcoal, but coke or cinders are generally used. Fresh coals are highly injurious to the work on account of the sulphur they contain, and soft or bituminous coal cannot be used at all until it is well charred or converted into cinders. Lead is equally as injurious in the fire for

brazing as for welding iron and steel, or in forging gold, silver, or copper, for the lead is oxidized and attaches itself to the metals that are being brazed or welded, and prevents the uniting of the metals; and in all cases it renders the metal brittle and unserviceable. There are many kinds of work which requires the application of heat having the intensity of the forge fire or the furnace, but in many of these cases it is only desirable to heat a small portion of the work and avoid soiling the surface of the remainder, and also to have the work under the observation and guidance of the operator, as in brazing or soldering small articles of jewelry, silver plate, etc. In these cases the blow-pipe and pointed flame is generally used, and in many cases the work is supported upon charcoal so as to concentrate the heat upon it.

BURNING TOGETHER.

The process of uniting two or more pieces of metal, by partial fusion, is called burning together. This operation differs from the ordinary soldering, in the fact that the uniting, or intermediate, metal is the same as those to be joined; and there is generally no flux used, but the metals are simply brought almost to the fusing point, and united together. The operation of burning together is, in many cases, of great importance, for when the operation is successfully performed, the work is stronger than when soldered, for all parts of it are alike, and will expand and contract evenly when heated; while in soldering, the solder often expands and contracts more, or less, than the metals which they unite; and this uneven contraction and expansion of the metal and solder, often tears the joint apart; and another objection to soldering is, that the solders oxidize either more or less freely than the met-

als, and weaken the joints, as is the case if lead vessels, or chambers, for sulphuric acid, are soldered with tin—the tin being so much more freely dissolved by the acid, than the lead, soon weakens or opens the joints.

Fine work, in pewter, is generally burned together at the corners, or any sharp angles of the work, where it cannot be soldered from the inside; this is done that there may be no difference of color in the external surface of the work. In this operation a piece or strip of the same pewter is laid on the parts to be united, and the whole is melted together with a large soldering iron, or copper-bit, heated almost to redness; the superfluous metal is then dressed off and leaves the metals thoroughly united, without any visible joint. In burning together pewter, or any of the very fusible metals, great care is required to avoid melting and spoiling the work.

Castings of brass are often united by burning together. In this operation, the ends of the two pieces to be united are filed, or scraped, so as to remove the outside surface, or scale; they are then embedded in a sand-mold, in their proper position, and a shallow, or open space is left around the joint, or ends of the castings; thirty or forty pounds of melted brass is then poured on to the joint, and the surplus metal allowed to escape through a flow-gate. In this way, two castings may be united so that they are as soldered as if they had been cast in one piece. This process is resorted to by all brass founders, in making large and light castings, such as wheels, large circular rims, etc.; when too large to be run in one piece, they are usually cast in segments and united by burning together.

Cast-iron is often united by burning together, or more properly, burning on, for in this case one of the metals added, or united, is in the fluid state. When about to burn on to a piece of casting, the part to be united to is scraped, or filed, perfectly clean, and is then em-

bedded in sand, and a mold of the desired shape formed around the casting; the metal is then poured into the mold and allowed to escape through a flow-gate until the surface of the casting is melted, and the metals unite, the same as in burning together of brass castings. In this way, small pieces that have broken off of large castings are burnt on, and cylinders that have had part of the flanges torn off, by blowing out of the heads, are repaired, by burning on a new flange, or the part that has been torn off. In burning on to cast-iron there are several very important points that must be observed in the operation, in order to make it a success. The ingate, as well as the flow-gate, should be made of a good size, so that the molten metal may be flowed through them rapidly, if necessary. The molten iron used should be the hottest that can be procured; and in pouring it into the gate it should be poured in rapidly, at first, and the metal allowed to run out freely at the flow-gate, so as to prevent the molten metal being chilled upon the surface of the casting. After the casting has been heated, in this way, the metal should be poured and flown through the gates slowly, so as to give the solid metal a chance to melt and unite with the fluid metal. After the surface of the metal has been melted, the pouring should be urged, so as to unite the metals more thoroughly; the operation should be continued for some time, so that the casting may be more thoroughly heated, and not be so liable to crack from uneven expansion and shrinkage.

The process of burning together, or mending, is often resorted to by stove-plate molders, for stopping small holes in the plates; this is done by laying the plate on the sand, with the sand firmly tucked under the part to be mended; a little sand is also put on top of the plate, around the part to be mended, so as to prevent the iron spreading over the plate; the molten iron is poured on the part to be mended, until the edges are

fused, and the surplus metal is then scraped off with the trowel, or a clamp-iron, while in the molten state.

HARD-SOLDERING.

Hard-soldering is the art of soldering or uniting two metals or two pieces of the same metal together by means of a solder that is almost as hard and infusible as the metal to be united. In some cases, the metals to be united are heated to a high heat, and their surface united without solder, by means of fluxing the surface of the metals. This process is then termed brazing, and some of the hard-soldering processes is also often termed brazing; both brazing and hard-soldering is usually done in the open fire, on the brazier's hearth.

When soldering work of copper, iron, brass, etc., the solder usually used is a fusible brass, and the work to be soldered is prepared by filing or scraping perfectly clean the edges or parts to be united. The joints are then put in proper position and bound securely together with binding wire or clamps; the granulated solder and powdered borax are mixed in a cup with a very little water, and spread along the joint to be united with a strip of sheet metal or a small spoon. The work is then placed upon a clear fire and heated gradually, to evaporate the water used in uniting the solder and borax, and also to drive off the water contained in the crystallized borax, which causes the borax to boil up with an appearance of froth. If the work is heated hastily, the boiling of the borax may displace the solder, and for this reason it is better to boil or roast the borax before mixing with the solder. When the borax has ceased to boil, the heat is then increased, and when the metal becomes a faint red, the borax fuses quietly like glass, and shortly after, as the heat of the metal is increased to a bright red, the solder also fuses, which is

indicated by a small blue flame from the burning of the zinc. Just at this time, the work should be jarred slightly by being tapped lightly with the poker or hammer, to put the solder in vibration and cause it to run into the joint. For some work it is not necessary to tap it with the poker, for the solder is absorbed into the joint and nearly disappears without tapping.

In order to do good work, it is necessary to apply the heat as uniformly as possibly, so as to have the solder melt uniformly. This is done by moving the work about in the fire. As soon as the work has been properly heated, and the solder has flushed, the work should be removed from the fire, and after the solder has set it may be cooled in cold water without injury. Tubes to be soldered are generally secured by binding wire twisted together around the tube with the pliers. All tubes that are soldered upon the open fire are soldered from within, for if they were soldered from the outside, the heat would have to be transmitted across the tube with greater risk of melting the lower part of the tube, the air in the tube being a bad conductor of heat, and it is necessary that both ends of the tube should be open so as to watch for the melting of the solder. In soldering long tubes, the work rests upon the flat plate of the brazier's hearth, and portions equal to the length of the fire are soldered in succession.

The common tubes or gas-pipe are soldered or welded from the outside. This is done by heating the tube in a long air furnace, completely surrounded by hot air, by which means the tube is heated more uniformly than in the open fire. After the tubes have been heated to the welding heat, they are then taken out of the furnace and drawn through clamps or tongs to unite the edges, and are then run through grooved rollers two or three times, and the process is complete. The soldering or welding of iron tubes requires much less precaution in point of the heat than some of the other metals

or alloys, for there is little or no risk of fusing it. In soldering light iron work, such as locks, hinges, etc., the work is usually covered with a thin coating of loam to prevent the iron from being scaled off by the heat.

Sheet iron may be soldered at a cherry red heat, by using iron filings and pulverized borax as a solder and flux. The solder and flux are laid between the irons to be soldered, and the whole is bound together with binding wire and heated to a red heat and taken from the fire and laid upon the anvil, and the two irons are united by a stroke upon the set hammer. Steel or heavy iron may be united in the same way at a very low heat.

For soldering iron, steel and other light-colored metals, and also brass work that requires to be very neatly done, the silver solder is generally used on account of its superior fusibility and combining so well with most all metals, without gnawing or eating away the sharp edges of the joints. Silver solder is used a great deal in the arts, and from the sparing or careful way in which it is used, most work requires but little or no finish after soldering; so that the silver solder, although expensive, is in reality the cheapest solder in the long run. For silver-soldering, the solder is rolled into thin sheets, and then cut into narrow strips with the shears. The joints or edges to be united are first coated with pulverized borax which has been previously heated or boiled to drive off the water of crystallization. The small strips of solder are then placed with forceps upon the edges or joints to be united, and the work is then heated upon the brazier's hearth. The process of silver-soldering upon the larger scale is essentially the same as the operation of brazing.

For hard-soldering small work, such as drawing instruments, jewelry, buttons, etc., the blow-pipe is almost exclusively used, and the solder used is of the finest or best quality, such as gold or silver solder, which is

always drawn into thin sheets or very fine wire, and it is sometimes pulverized or granulated by filing; but if solder is pulverized very fine, a greater degree of heat is required to fuse it, for a greater degree of heat is always required to fuse a minute particle of metal than is required to fuse a large piece.

In soldering jewelry, the jeweler usually applies the borax, or other flux, in solution, with a very small camel's-hair brush. The solder is rolled into thin sheets and then clipped into minute particles of any desired shape or size, which is so delicately applied to the work that it is not necessary to file or scrape off any portion of it, none being in excess. The borax or other flux used in the operation is removed by rubbing the work with a rag that has been moistened with water or diluted acids.

SOFT-SOLDERING.

Soft-soldering is the art of soldering or uniting two of the fusible metals, or two pieces of the same metal. The solder used is a more soft and fusible alloy than the metals united, and is termed soft-solder; and as it is very fusible, the mode of applying the heat is consequently very much different from that employed in hard-soldering.

The soft-solders are prepared in different forms to suit the different classes of work for which they are intended. Thus, for tin soldering it is cast into bars of ten or twelve inches long by one inch wide, and by some it is cast into cakes ten or twelve inches long by three or four inches wide.

The plumber's solder is generally cast into small ingots or cakes, two or more inches square, according to the work for which they are intended, and size of pot they are to be melted in. Some of the very fusible

solders that are intended for very light work are trailed from the ladle upon an iron plate, so as to draw the solder into thin or large bars, so that the size of the solder may always be of a size to suit the work that it is used upon. In soft-soldering it is very essential that the parts to be united should be perfectly clean and free from any metallic oxides, and for this reason the parts to be united are generally wet with a little chloride of zinc before applying the solder; and when the metal is old or very dirty, it must be scraped on the edges intended to be united before applying the solder.

When soldering lead pipe, sheet lead, etc., the plumber first smears a mixture of size and lampblack around the intended joint, to prevent the melted solder adhering to the metal at a point where it is not wanted. The parts to be united are then scraped quite clean with the shave-hook, and the clean metal is then rubbed over with tallow. The wipe joints are usually made without using the soldering-iron. The solder is heated in the plumber's pot rather beyond its melting point and poured plentifully upon the joint to heat it. The solder is then molded into the proper shape and smoothed with the cloth or several folds of thick bed-ticking, which is well greased to prevent burning, and the surplus solder is removed with the cloth.

In forming the striped joint the soldering iron and cloth are both used at the commencement in molding the solder and heating the joint. In forming this joint less solder is poured on than when forming the wiped joint, and a smaller quantity remains upon the work. The striped joints are not so neat in appearance as the wiped joint, but they are claimed by many to be sounder from the solder having been left undisturbed when in the act of cooling. But in the wiped joint the body of the solder is heavier, and the shrinkage of it around the pipe is sufficient to unite the pipe even if the solder does not thoroughly unite with the pipe. In forming

joints on lead pipe the cloth is always used to support the fluid solder when poured on the pipe. Light lead work, that requires more neatness than the ordinary plumbing, is usually soldered with the ordinary tinner's soldering-iron.

The tinner's soldering-iron, as it is commonly called, is made of a square piece of copper, weighing from three or four ounces to three or four pounds, according to the size of work it is intended for. This piece of copper is drawn down to a long, square point, or to flat wedge-shape, and riveted into an iron shank, and the shank fitted with a wooden handle. The copper-bit, or soldering-iron, is then heated in the tinner's fire-pot with charcoal to a dull red-heat, and is then screwed in the vise and hastily filed to a clean metallic surface. It is next rubbed upon a piece of sal-ammoniac, or on some powdered resin, and then upon a few drops of solder in the bottom of the soldering-pan. In this way the soldering-iron is thoroughly coated with tin, and is then ready for use.

In soldering tin-plate work, the edges are slightly lapped over each other, and the joint or seam is strewn with powdered resin, which is usually contained in a small box set in the soldering-pan. The soldering-iron, which has been heated in the fire-pot, is then drawn over the cake of solder, and a few drops are melted and adhere to the soldering-iron, and is distributed by it along the joint or seam. In large work the seams are first tacked together, or united by drops of solder so as to hold the seams in proper position while being soldered ; but this is seldom done in small work, which can easily be held together with the hands. Two soldering-tools are generally used, so that while one is being used for soldering, the other one is being reheated in the fire-pot, and thus avoiding the delay of waiting for the tool to heat. The temperature of the tool is very important, for if it is not hot enough to

melt the solder, it must be returned to the fire ; and if it gets too hot the tinning will be burnt off and the solder will not hang to it, and the tool must be re-tinned before it can be used. In soldering tin-ware, the tool is usually passed only once over the work, being guided by contact with the fold or ledge of the seam ; but when the operator is not an expert, he usually runs the tool backward and forward over the work two or three times. This makes slow work.

Sheet-copper, in common work, is soldered with the soldering-iron in the same manner as sheet-tin, but the finer or more important work is brazed or hard-soldered. In soft-soldering copper, as well as sheet-iron, the flux generally used is powdered sal-ammoniac, or a solution of sal-ammoniac and water. A piece of cane, the end of which is split into filaments to make a stubby brush, is used for applying the solution to the work, and powdered resin is subsequently applied. Some workmen mix the powdered sal-ammoniac and resin together before applying it to the work. This, they claim, is better than applying them separate, but so long as the metals are well defended from oxidation, either of the modes is equally as good, for the general principle is the same in both. Zinc is the most difficult metal to solder, and the joints or seams are seldom so neatly formed as in tin or copper. Zinc will remove the coating of tin from the soldering-tool in a very short time. This arises from the superior affinity of copper for zinc than for tin, and the surface of the tool is freed from tin and is coated with zinc. Sal-ammoniac is sometimes used for a flux in soldering zinc, but the most common flux used for zinc is muriate of zinc, which is made by dissolving fragments of zinc in muriatic acid diluted with about an equal amount of water. This solution is put in a wide-mouthed bottle, and small strips of zinc dropped into it until they cease to be dissolved. The solution is then ready for use, and is

termed muriate of zinc. This solution is likewise used for almost all the other metals, as it can be used without such strict necessity for clean surfaces as when some of the other fluxes are used.

In soft-soldering, the soldering-iron is only used for thin sheet metals, because, in order to unite two metals, by soldering, the temperature of the metals must be raised to the melting point of the solder; and a heavy body of metal cannot be sufficiently heated with the soldering-iron, without heating it to too great a heat, which is apt to either burn off the coating of tin, or to cause it to be absorbed by the copper, as in superficial alloying, and the solder will not adhere to the tool, and cannot be spread along the joint by it; and in soft-soldering heavy work, the work is first filed, or scraped, perfectly clean, at the points to be soldered, and is dipped into a bath of melted solder, which is covered with a little melted sal-ammoniac, to prevent oxidation, and also to act as a flux for uniting the metals. In dipping the work into the bath, it first comes in contact with the flux, and is coated by it before it is subjected to the heat; and when dipped into the solder the tin readily adheres to it; and after heavy pieces of metal have been tinned, in this way, or by the process of dry-tinning, with mercury, they may be soldered with the soldering-iron.

When tinning thin pieces of brass, or copper alloys, for soldering, it is usually done by rubbing a few drops of solder over the part to be tinned, with the soldering-iron; and if tinned by dipping into a bath, it must be quickly dipped, or there is a risk of the thin sheets being melted by the solder.

When tinning iron, or steel, the work must be allowed to remain in the bath, for some time, so as to be thoroughly heated by the bath, or the tin will not be thoroughly united to the iron or steel, and may peel off when cold. Large pieces of iron, or steel, that are in-

convenient to dip into a bath, are tinned by heating in the open fire, and rubbing the solder on with the soldering-iron, using either sal-ammoniac, or resin, as a flux. When tinning, in this way, the lowest heat that will fuse the solder should always be used.

TABLE OF METALS

The following table of the metals has been inserted at this point so as to be handy to refer to in forming alloys, and avoid turning to the respective metals to ascertain their specific gravity and fusing point; two very important items that should always be taken into consideration when forming alloys; for if we unite a heavy metal and a light one, the heavy metal will settle to the bottom of the ladle or casting, if the metal is not well stired, and the casting cooled quickly. If we unite two metals, one of high fusion and the other of low fusion, the metal of high fusion should always be melted first, and the metal of low fusion added while it is in the molten state, so as to avoid wasting the more fusible metal:

NAME.	Atomic Weight	Specific Gravity.	Specific Heat.	Color.	Fusing Point.
Aluminum	27.5	2.67	.2143	white	1292 F.
Antimony	122	6.71	.05077	bluish-white	812° F.
<i>Arsenic</i>	75	5.95	.08140	steel-gray	774° F.
Barium	137	1.85	.....	yellow	.....
Bismuth.....	210	9.799	.03084	reddish-white	507° F.
<i>Boron</i>	11	2.680	.2500	brown	.....
<i>Bromine</i>	80	3.187	.1060	brownish-red	45° F.
Cadmium.....	112	8.604	.05669	bluish-white	420° F.
Cæsium.....	133	unknown	.....	.....	.....
Calcium.....	40	1.578	.....	light yellow	.....
<i>Carbon</i>	12	2.35	.02411	black	infus.
Cerium.....	92	.....	.....	.....	4200°
<i>Chlorine</i>	35.5	2.435	.1214	green	.....
Chromium.....	52.5	6.810	.....	gray	4000°
Cobalt.....	59	8.95	.10696	steel-gray	2000° F.
Copper.....	63.5	8.90	.09515	red	1994° F.
Didymium.....	96	.....	.....	.....	.....
Erbium.....	112	.....	.....	.....	.....
<i>Fluorine</i>	19	1.31	.....	.....	.....
Glucium.....	9.5	2.10	.....	.....	.....
Gold (Aurum)....	197	19.34	.03244	yellow	2015° F.(?)
Hydrogen.....	1	.069 #	3.4046	colorless	.....
Indium.....	76	7.20	.....	white	349° F.
<i>Iodine</i>	127	4.94	.05412	bluish-black	225° F.
Iridium.....	197	21.80	.03259	white	O-H
Iron.....	56	7.80	.11379	gray-white	1900 to 2900
Lanthanum.....	92	.....	.....	.....	.....
Lead (Plumbum)..	207	11.36	.0314	bluish-white	620° F.
Lithium.....	7	0.59	.9408	white	324° F.
Magnesium.....	24	1.70	.2499	white	446° F.
Manganese.....	55	8.00	.1217	gray-white	4096°
Mercury.....	200	13.596	.03332	white	—39° F.
Molybdenum.....	96	8.64	.....	gray	4400°
Nickel.....	59	8.90	.10863	white	2732°
Niobium.....	94	.....	.....	.....	.....
<i>Nitrogen</i>	14	.97	.2440	colorless	.....
Osmium.....	199	21.400	.03063	bluish-white	infus.
<i>Oxygen</i>	16	1.1056	.2182	colorless	.....
Palladium.....	106	11—12	.05927	white	4000° (?)
<i>Phosphorus</i>	31	1.83	.1887	colorless	110°
Platinum.....	197	21.53	.03243	white	4591° F.(?)
Potassium.....	39	865	.16956	bluish-white	136°
Rhodium.....	104	11.00	.05803	.....	4200°
Rubidium.....	85	1.52	.....	white	101°
Ruthenium.....	104	11—12	.....	.....	.....
<i>Selenium</i>	79.5	4.80	.0837	brown	423°
<i>Silicon</i>	28	2.49	.....	brown	.....
Silver.....	108	10.50	.05701	white	1873° F.
Sodium.....	23	.972	.2934	white	195°
Strontium.....	87.5	2.54	.....	pale-yellow	.....
<i>Sulphur</i>	32	2.00	.1776	yellow	228°
Tantalum.....	182	10.78	.....	.....	.....
<i>Tellurium</i>	129	6.65	.04737	reddish-white	716°
Thallium.....	204	11.86	.03355	white	554°
Thorium.....	238	.....	.....	.....	.....
Tin.....	11	7.3	.05623	white	442° F.
Titanium.....	50	5.3	.....	gray	4000°
Tungsten (Wol- framium)..... }	184	17.50	.03342	steel-gray	4000°
Uranium.....	120	18.40	.....	gray	4300°
Vanadium.....	51	3.64	.....	.....	.....
Yttrium.....	62	.....	.....	.....	.....
Zinc.....	65	7.15	.9555	bluish-white	773° F.
Zirconium.....	89	4.15	.....	black	.....

NOTE.—All the names printed in Roman letters indicate metals, and those in *italics*, non-metals.

G O L D .

Gold is a yellow metal. Its fusing point is 2015° Fahrenheit's scale, and when in fusion appears of a brilliant greenish color. Pure gold is nearly as soft as lead; it is extremely malleable and ductile. It does not oxidize at any temperature, and on account of its indestructibility it was anciently called the king of the metals.

Gold is found sometimes in masses called nuggets, but generally in scattered grains or scales. As the rock in which it occurs disintegrates by the action of the elements and forms soil, the gold is gradually washed into the valleys below and thence into the streams and rivers, where, owing to its specific gravity, it settles and collects in the mud and gravel of the beds. As the metal is thus found native, the process of preparation is purely mechanical, and consists simply in washing out the dirt and gravel in wash-pans, rockers, sluices, etc., at the bottom of which the gold accumulates. In the quartz-mills the rock is thrown into troughs of water, where, by heavy stamps, the ore is crushed to powder. It is then washed with water, and the gold obtained.

At the present time the State of California stands pre-eminent in the production of gold. The gold in this State is found native, in small grains, in spangles, and in crystals so small as to be almost invisible to the naked eye, and also in nuggets of ten and fifteen pounds weight. These grains of gold are often found in small particles of rock that have been worn off by the action of the elements. They are found imbedded in masses of quartz, and they are sometimes found mechanically enclosed in quartz-rock. They are found in the gravel of hills from the surface to the bed-rock, sometimes a depth of three to five hundred feet; in the

alluvial soil of the plains, and even in vegetable loam among the roots of grass. But in most cases the grains are pure gold alloyed with a little silver. This alloy of silver diminishes the value of the California gold about fifteen or twenty per cent. The gold of California was formerly exclusively procured from the alluvial sand and gravel on the banks of the rivers, and in the valleys traversed by mountain streams; but of late years machinery has been invented and introduced for crushing and pulverizing the quartz-rock, and from this rock our principal supply of gold is obtained at the present time, although large quantities are still obtained from the alluvial sand and gravel. The implement used to procure the gold from the alluvial sand or gravel is most simple, and consists simply of an iron or tin wash-pan. When this pan is filled with sand and gravel, it is immersed in water and shaken; the gold sinks to the bottom, and the sand, clay and gravel flow off with the water or are taken out by hand. There is no doubt that a large quantity of gold is lost in this way of washing, for gravel and sand have been washed the second time and almost as much gold obtained as at the first washing. Where the washing of either the alluvial soil or crushed quartz is carried on, on a large scale, it is done in sluices. These are gently-inclined troughs, sometimes extending for miles. Across the bottom of the troughs are fastened low wooden bars called rifles, above which quicksilver is placed. The dirt is shoveled into these sluices, and washed through them by powerful streams of water which are constantly running; the water floats off the dirt, while the mercury catches the gold. The greater part of the mercury is separated from the amalgam by pressure in canvas or buckskin bags, the liquid mercury escaping through the pores, while the amalgam is left quite dry. The amalgam is then retorted and the balance of the mercury removed by evaporation.

Large quantities of gold are found in all the Western territories as well as in California. The deposits are about the same as those of California, and they are worked and the gold obtained in the same way as in California.

There are also gold-bearing localities in the States of Virginia, North Carolina, West Virginia, New Hampshire and several other States; but these regions are not so productive as those of the Far West, and they have generally been abandoned since the California gold excitement of 1849.

There were formerly alluvial gold diggings in the Southern States which yielded as well as the best California diggings. Such diggings furnished, some years ago, large quantities of gold, but the abundant yield did not last long. The rich deposits were soon exhausted, and the poorer localities did not pay for working. The gold-bearing rock is chiefly a talcose slate, which is a slate resembling soap-stone, but which does not feel so greasy. This slate is red and ferruginous at the surface. At a greater depth it is filled with small crystals of iron pyrites, which are decomposed near the surface, and appear as peroxide of iron, which colors the slate brown, and in a few instances, yellow. This slate is of various grades of hardness, which is caused by the influence of more or less heat when it was formed in the North Carolina gold-diggings. It is generally very hard. Native gold is also found imbedded in quartz-rock, in which it appears in crystals, plates, grains, and also in perfectly developed veins, but these veins only shoot through between the crystals of the quartz-rock, and are not continuous. Quartz of this description is found in Virginia, North Carolina, and Georgia, but the best gold-producing quartz is found in California and the Western Territories. This quartz has never been found in a regular continuous vein, but is only found in small lodges, which makes it difficult

and expensive to work. Gold never appears in solid veins. It is always disseminated through the mass of the rock, in some places more dense than in others. There are localities in the gold regions of the West where every piece of rock, every handful of soil, contains more or less of this precious metal; but it is often in such fine grains as to be not only invisible to the naked eye, but undiscernible even with the assistance of a powerful glass. This is the case even when the ores are worth four or five dollars per bushel. Yet, by natural or artificial decomposition of these ores, the gold becomes visible, and sometimes appear to be in large grains. Some veins of ore contain coarse gold in grains as large as the head of a pin, and even larger. These are generally found in the quartz-veins, in which the pyrites are concentrated into large masses. In the fresh pyrites the gold is invisible even if, after separation, it appears to be coarse.

The talcose gold-bearing slate is a metamorphic rock. It runs in a regular belt parallel with the Alleghany mountain chain. This gold-bearing belt is thirty or forty miles in width, and can be traced in a southerly direction through the States of New Jersey, Pennsylvania, Maryland, Virginia, North and South Carolina, Georgia and Alabama. In the latter State it seems to sink beneath the Mississippi river, and it probably rises again to the surface near the Rocky Mountains. Within this belt the various veins of gold-bearing slates are distributed. Those parts of the veins which are richest in gold are characterized by small veins of quartz running parallel with the slate. Where this quartz is wanting, not much gold is to be found. The talcose gold-bearing slate of California is particularly distinguished in this respect, and it is said that they are the richest gold-bearing ores in the world. The direction of the talcose veins is parallel to the general course of the rocky strata or formation that is north-east to south-

east. These veins are often twenty feet thick and upward. They are pyriteous, and contain iron, copper, and sulphurets of lead, which are found sometimes to be rich in gold. It is the general impression, when gold is found in alluvial soil, or in the bottom of a stream, that a vein of gold ore must exist somewhere about that place where the gold is found ; but this impression, however plausible, is false ; for we find gold-washings in the alluvial deposits of granite mountains. Still there are no gold-bearing veins found in this rock. Yet gold is never carried far from its original resting-place, and if a vein of gold ore cannot be found near the alluvial washings, there is no prospect of finding it either above or below where the stream ceases to carry it.

Gold is seldom found in veins, except in the very rich quartz, but is mostly found distributed through masses of rock ; this rock is dissolved by the action of the elements, and the gold is washed into the streams, or deposited in the alluvial soil. Where the streams contain more gold, after heavy rains and freshets, it is an indication that there is no gold-vein, from whence the gold is produced ; but the gold comes from the rocks which have been dissolved by the action of the elements, and washed into the streams by the heavy rains. Where the gold is found in a stratum, in an alluvial deposit, it is an indication of there being no vein, for a severe winter, or a heavy freshet, will cause the formation of this stratum, while a vein would furnish a regular supply, and not form a stratum. The quantity of gold obtained from these strata, or washings, may be very promising, at first, but they are seldom continuous ; yet, if the washings, in the alluvial deposits are not carried on too extensively, a regular yearly supply may be obtained, but the crop of gold will depend upon the dissolving of the rocks, and the quantity of rain which falls, to wash the fine particles of gold down into the streams, or soil. The yield of gold from the

alluvial deposits, is, sometimes, very valuable; a fortune may sometimes be obtained from a few bucketsful of sand. The first miners who arrived at Pikes Peak, and other rich deposits of gold, made a fortune in a short time, and it will be the same at the Black Hills; but these rich deposits are only found in spots, and when these spots are exhausted, there is no vein to fall back upon, and it requires a number of years, perhaps ages, to accumulate another heavy deposit of the metal. In these deposits of gold, lumps have been found worth five and six thousand dollars.

Gold is never found in the secondary strata of rock, or in the coal regions; we may look in vain for it on the western slope of the Alleghany mountains; it cannot be found there; it appears to have originated in the primitive rocks, and it is most abundantly found in the rocks of igneous origin—the geological formation of California is of this character, and is rich in gold; but the rocks of the southern gold-bearing strata is not of igneous origin. The gold, in this latter region, is evidently produced from the pyrites, which may be a secondary enclosure. This theory is supported by the fact that the richest gold ores are found near veins of rock that are of the igneous strata. All native sulphurets, particularly all the sulphurets of iron, or silver, contain gold, but all pyrites do not contain sufficient gold to pay for its extraction. As sulphur cannot penetrate any rock, but from below, we must naturally conclude that the heaviest body of the pyriteous ores must lie deep in the earth; this conclusion is supported by practice, for all pyriteous veins are invariably found to improve in quality and quantity with the depth.

Gold is also found inclosed in crystallized quartz. This gold has, evidently, been washed into the crevices of the rocks, and afterwards covered with quartz, in solution; and to this result the heat of a volcanic region has, no doubt, greatly contributed. The crevices of the

felspathic rock, of North Carolina, are chiefly filled with crystalline quartz, which, in many instances, contain gold.

The work of obtaining gold from its ores, is a work that requires great care, to make it profitable; for, in crushing, washing and amalgamating these ores, a large portion of the gold may be wasted, which, in poor ores, may amount to fifty per cent. Ores which yield twenty-five cents worth of gold, by amalgamation, yield fifty cents by smelting them. The best way to obtain all the gold from its ores, by amalgamation, is to amalgamate the ores two or three different times. In works for the refining of gold, great care is taken to avoid the loss of any particles of the metal; all the old crucibles are ground, and treated with mercury, and after as much gold as possible has been obtained, the residues are melted with lead, and a little more extracted; all the dust off the floor is collected and treated in a similar way.

The floor of the alloy-room of the United States Mint, at Philadelphia, Pa., is made of pipe set on end with the top end open, and all the dust and fine particles of gold that is lost goes down the pipe. These pipes are removed once a year, and all the dirt is amalgamated or smelted, and all the gold obtained. It is said that as high as thirty thousand dollars have been taken from these pipes in one year.

Gold is not much used in the arts in its pure state; it is then too soft to be durable. The gold leaf used by dentists for stopping decayed teeth is, perhaps, as near pure as the metal can be obtained; it contains about one-thousandth part of alloy. Gold is used with other metals in forming alloys for coin, jewelry, ornaments, etc. Gold is also extensively used for plating other metals by the electrotype process and for gilding. In water gilding, fine gold is amalgamated with mercury, and rubbed over the metal intended to be gilded, the

mercury attaches itself to the metal, and when evaporated by heat it leaves the gold behind in the dead or frosted state; it is then brightened with the burnisher. Finé gold is also used for soldering chemical vessels made of platinum. Gold is more ornamental than useful. (See ALLOYS.)

SILVER.

Silver is the whitest of the metals, its fusing point is 1873 of Fahrenheit's scale. It is malleable and ductile; it expands at the moment of solidification, and therefore cannot be cast. It has a powerful attraction for sulphur, forming silver sulphide, silver spoons, and knobs are tarnished by the minute quantities of hydro-sulphuric acid present in the air.

Silver is found through the west in a great variety of forms, most commonly, however, combined with sulphur, as black sulphide with chlorine, forming horn-silver, and with sulphur and arsenic or antimony forming ruby-silver. The sulphides and sulphurets of silver is the most common of the silver ore. We find it in the form of crystals, hairs and needles, or like wire twisted into nets, in plates and in shapeless masses. This ore is not elastic like metallic silver, yet it is malleable, and may easily be cut with a knife; the clean cut looks like metallic lead, but it is soon covered with a film of oxide of various colors. These sulphide ores of silver contain as high as eighty-five per cent of silver and fifteen per cent of sulphur. They are easily smelted, and metallic silver is obtained from them with but little trouble. The sulphuret of silver, and all the ores of silver, are found in rocks of all ages, except in the coal regions. The sulphuret of silver is the chief source from which we obtain our supply of silver. It is found in abundance in almost all of Western and Southern gold regions,

where it appears in heavy veins, associated with gold, copper, lead, antimony, arsenic and other metals. Silver is most abundantly found where mineral veins cross or meet each other, and in the copper mines of Lake Superior silver is often found mixed with the copper, but in distinct fibers, not being alloyed with the copper. The silver ores of the gold regions contain the sulphurets of zinc, some iron pyrites and copper pyrites, and in some cases a little tin or arsenic. The silver is generally found to be alloyed with these metals as well as with gold. The amount of silver in these ores are variable; from some ore only ten or fifteen ounces can be obtained from a ton of crude ore, and from others as high as sixty or seventy ounces may be obtained. An ounce of silver from these ores is worth as high as two dollars; the high price paid for it is on account of the small amount of gold that is alloyed with it. Some of the silver ores of the gold region are very rich in gold, and are often worked more for the gold they contain than the silver. The silver is obtained from these ores principally by the smelting process, but the refined silver is obtained by crushing the ore into a fine powder, and then roasting it with common salt, the chlorine of the salt unites with the silver forming silver chloride. This is next put into a revolving cylinder with water mercury and iron scraps, the iron removes the chlorine from the silver, when the mercury takes it up, thus forming an amalgam of mercury and silver; from this amalgam the silver is obtained in the same way as from the gold amalgams.

The chloride of silver is found native, and is called horn-silver. It is chiefly found at the outcrop of veins along with native silver, but is not so generally found as the sulphurets of silver. Chloride of silver is a very horny substance, and is so soft as to be cut by the finger-nail. The chloride of silver is of different colors, but is generally of a gray or greenish color. Silver is

also found combined with sulphur and antimony, or arsenic. In this form it is termed ruby silver. Its color embraces all the shades of red, and is rarely found of any other color. It is found wherever other silver ores are found, and is generally accompanied by or associated with antimony or arsenical ores.

The antimonial silver ore is the richest of silver ores. It is found in California and all of our Western Territories in great abundance. It is a crystallized ore of a yellowish-blue color, hard, and very brittle. It resembles arsenical iron, but is easily distinguished from that ore by its crystals being longer and not so hard. This ore, when pure, contains as high as eighty per cent. of silver and twenty per cent. of antimony. From this ore and the sulphuret ores our principal supply of silver is obtained. They are both found in the Western Territories, and are extensively worked, so much so that silver has come to be as plentiful as iron in some parts of the West; and in San Francisco, California, silver coin has become so plentiful that the business men do not know what to do with it, for it is too heavy to be carried or handled in large quantities.

Silver is but little used in its pure state on account of its extreme softness; but it is generally alloyed with copper in different proportions and used for coin, jewelry, ornaments, etc. It is also used for plating other metals by the electrotype process, which it does in the most uniform and perfect manner. The silver added is charged for by weight at about three times the price of the metal. The German silver is generally used for the interior substance, as when the silver is partially worn through, the white alloy is not so readily detected as iron or copper would be. Diamonds are set in fine silver containing from three to twelve grains of copper in the ounce. The work is soldered with pure tin. The sheet-metal for plated work is prepared by fitting together very truly a short, thick bar of copper, and a

thinner plate of silver. They are tied together with binding-wire, and united by partial fusion without the aid of solder. The bar is then rolled out into sheets, and the silver always remains perfectly united and of the same proportional thickness as at first. Silver cannot be used in its pure state for casting, for at a temperature a little above the melting-point it absorbs oxygen, which it gives off as it approaches the point of solidification, and when a thin crust of metal has formed upon the surface, the silver beneath it appears to boil, and the crust is forced up into hollow cones through which the molten silver is thrown out with explosive violence, and sometimes solidifying into most fantastic, tree-like forms. (See ALLOYS.)

PLATINUM, PALLADIUM, RHODIUM, IRIDIUM AND OSMIUM.

These five metals are called the platinum metals, because they always appear together, or are alloyed. These metals are as valuable as gold, and some of them are sold at higher prices than gold. When pure, they are heavier than gold. All of them are almost infusible when pure, but may be fused when slightly impure, or when alloyed with other metals.

P L A T I N U M .

Platinum is a white metal, and resembles silver in its appearance; it is the most infusible of metals, and is unaltered by the joint action of heat and air, and can be melted only by the heat of the compound blow-pipe, or voltaic battery. It is one of the most ductile of metals, wire being made from it so fine as to be invisible to the naked eye. It does not oxidize in the air.

Platinum is chiefly found in the Ural-mountains, where it occurs in alluvial deposits, usually in small, flattened grains. It has been found in the gold diggings of North Carolina, Georgia, Virginia and California, but not in such quantities as to be of any importance. The largest nugget of platinum ever found weighed eighteen pounds. Platinum being nearly infusible, when pure, requires a very different treatment from other metals, and in place of fusion it is first dissolved, chemically, and it is then thrown down in the state of a precipitate; next, it is partly agglutinated in the crucible into a spongy mass, and is then compressed, while cold, in a rectangular mold, by means of a powerful press, or other means; two blocks, or pieces, are then heated, in a smith's forge, with two tuyeres, meeting at an angle, at which spot the platinum is placed amidst the charcoal fire; when heated to the welding point, or almost a blue heat, it is then welded as iron; several heats are generally required to make a perfect weld.

Platinum is used for crucibles, in chemical laboratories; in Russia, it is used for coin; it is also used for the touch-holes of fowling-pieces, and in various philosophical apparatus, in which resistance to fusion, or to acids, are essential. (See ALLOYS.)

PALLADIUM.

Palladium is a dull-white colored metal; it is almost infusible, when pure; and it is very soft, malleable and ductile.

Palladium is generally found alloyed with platinum, in its native state, and is separated by dissolving in acids. Palladium is used for many of the purposes for which gold and platinum are applied—in the useful arts, and in many of the alloys. With silver, it forms

a very tough, malleable alloy, fit for the graduation of mathematical instruments; and for dental-surgery, for which purpose it is much used by the French. With silver and copper, palladium makes a very springy alloy, used for the points of pencil-cases, tooth-picks, or any purpose where elasticity, and the property of not tarnishing, are required—thus alloyed, it takes a high polish.

Palladium was used in the construction of the scales for the United States Mint.

R H O D I U M .

Rhodium is a white metal; it is almost infusible, when pure; and is extremely hard, when pure. The acids do not dissolve it. It is generally found alloyed with platinum and palladium. It has long been used for the nibs of pens.

I R I D I U M .

Iridium is named from Iris, the rainbow, because of the beautiful color of its salts. It is a very hard metal, and almost infusible, when pure. It is used with osmium, or rhodium, in forming an alloy for pen-points.

Iridium is generally found associated with platinum.

O S M I U M .

Osmium is a very hard metal, and almost infusible, when pure. It is found with platinum, and, like iridium, is very scarce and valuable. It is scarcely used for any other purpose than in alloys for pen-points.

M E R C U R Y .

Mercury is also called quicksilver, because it runs about as if it were alive, and was supposed by the alchemists to contain silver. It has been known, however, from very remote ages. The mines of Spain were worked by the ancient Romans. It is liquid at all common temperatures, and contracts considerably at the moment of congelation. It boils and becomes vapor at about 670° of Fahrenheit's scale.

Mercury is found native in all mercury mines. It occurs in small drops attached to the body of the ore, to the gangue or dead minerals of the veins, and to the rocks. The most important ore of mercury is cinnabar. This ore resembles in color oxide of iron, with which it is sometimes confounded. Its redness, however, is mingled with a yellowish hue like that of minium, by which peculiarity it is distinguished. It is also easily distinguished from other minerals by its volatile character. It evaporates entirely when thrown in a fire, leaving no residuum, and emitting a strong smell of sulphur. Cinnabar is found in the Western States and territories, and is said to occur in heavy masses. Bituminous sulphuret of mercury is also a mercury-producing ore. It is of a more or less gray-brown, earthy color and appearance. There are other ores of mercury, but they are of little importance.

Mercury is found native in Mexico in very small quantities, where the mines are said to have been discovered by a slave, who, in climbing a mountain, came to a steep ascent. To aid him in mounting this, he tried to draw himself up by a bush which grew in a crevice above; the bush, however, giving way, was torn up by the roots, and a tiny stream of what seemed liquid silver trickled down upon him.

Mercury is used in the fluid state in the manufacture

of thermometers and barometers, and for pressure gauges, in silvering mirrors, and for extracting the precious metals from their ores. It is sometimes, although rarely, employed for rendering alloys more fusible. It forms amalgams with gold, silver, copper, palladium, tin, lead and zinc.

C O P P E R .

Copper is a reddish metal; its fusing point is 1994° of Fahrenheit's scale. It is ductile and malleable, and is an excellent conductor of heat and electricity. It exhales a peculiar smell when warmed or rubbed; it melts at a bright-red or dull white heat.

Copper is found native in large quantities, in regular veins, near Lake Superior, and frequently in masses of great size. The heavy masses of copper in these places are imbedded in volcanic rock, and small veins ramify it in all directions. It occurs in bodies of almost every size, from small grains to masses weighing ten tons and upwards. This native copper is frequently found to be mixed with silver in distinct fibre, the latter not being alloyed with the copper. In these mines stone hammers have been discovered, the tools of a people older than the Indians, who probably occupied this continent and worked these mines. In the Western mounds, also, copper instruments are found, and it is thought that the mound-builders of the Western and Southwestern States worked these mines. Native copper is found in almost every vein of copper ore. It has been found in those of New Jersey, and also in those of Pennsylvania and some of the Western territories. Copper ores are, like iron ores, very abundant, and there is a great variety of them. They are found in almost every State in the Union. Copper ores are smelted on the same principle as iron ores—by heating with carbon.

The ores from which copper is principally smelted are the sulphuret ores, the copper pyrites, the red and black oxides, the carbonates of copper, and others. The sulphuret ores are the ones from which the most copper is smelted. There are two kinds of these ores : one is called the gray sulphuret of copper, the other, copper pyrites. The pyrites generally contain more or less iron, and it resembles iron pyrites very much, but may be easily distinguished from it by its lively, rainbow colors. The iron pyrites are always found with the copper pyrites, and the best ores contain from ten to twenty per cent. of iron and forty or fifty per cent. of copper, while some of the poorer ores only yield three or four per cent. of copper. These pyrites ores are found in most all the metamorphic rocks of the United States, particularly around the lakes, all along the Atlantic coast, and through the Rocky Mountains. The copper pyrites are very abundant, but are frequently so mixed with other matter as to make the mining and smelting of them unprofitable. They are commonly associated with iron. In New York, New Jersey, and Eastern Pennsylvania, they are mixed with magnetic iron, and in Vermont and North Carolina with the sparry carbonates of iron, and with iron pyrites everywhere. The copper pyrites generally accompanies the gold-bearing iron pyrites in all cases, and is considered a good indication of richness. Copper is also found with sparry-iron, galena, and sulphuret of zinc. But there is very few instances in which any of these ores will pay for working, as they rarely yield more than four or five per cent of copper.

The gray sulphuret of copper is a compact ore. Its surface is a dull lead-color, or an iron-gray. It is also found of a faint red-color when taken near the surface of the ground. It is very easily smelted, and yields a large percentage of copper when the ore is pure. This

ore is found in heavy veins in the copper regions of Lake Superior, and also in New Jersey.

The red oxide and black oxide ores of copper are not very plenty, and are little used for the production of metallic copper.

The carbonate of copper is generally of a blue color, but it is also found of all shades, from dark-blue to light green. This class of ore is of little value, and is more of a curiosity than a useful ore.

The phosphates and chlorides of copper are both of a green color, and form no regular copper ores.

There are several other copper ores, but those described are the principal ores from which our supply of copper is obtained. There is scarcely any of the copper ore which does not betray the presence of that metal by a green film.

Copper is extensively used with other metals in forming alloys of brass, britannia, bronze, German-silver, hard-solder, etc. It is also used alone for many purposes, such as sheathing and bolts for ships, brewing, distilling, and culinary vessels, rolls for calico printing, paper-making, plates for the use of engravers, etc. (See ALLOYS.)

Z I N C .

Zinc is a bluish-white metal, with considerable lustre, and rather hard. It melts at about 773° of Fahrenheit's scale. It is ordinarily brittle, but when heated to a little above 200°, and between that and 300°, it becomes ductile and malleable, and can be rolled out into the sheet-zinc, in common use, or be drawn into moderately fine wire, which, however, possesses but little tenacity.

Zinc, when melted, burns in the air with a magnificent green light, forming flakes of zinc-oxide, sometimes called "Philosopher's Wool." When exposed to the

air zinc soon oxidizes, and the thin films of white oxide, formed over the surface, protects it from further change.

Native zinc, or spelter, as it is called in commerce, is never found; it has so much affinity for other matter, particularly oxygen, that it cannot exist very long in its pure state. The principal ores of zinc are zinc-blende, red zinc ore, and calamine ore. The zinc-blende is a sulphuret of zinc, and is composed of sixty or seventy per cent of zinc, and the balance sulphur; its color is generally a bright or yellowish-brown, but it is occasionally found of a black, red, green or yellow color. This ore is always found crystallized, and in most cases the masses of it are mere accumulations of crystals. It is transparent, or, at least admits of the passage of light, if in thin scales. This ore is found in heavy veins and masses, in the gold regions of the western territories and southern states. It sometimes contains silver, and also gold, in considerable quantities. It is sometimes associated with Galena iron and copper pyrites, tin, heavy spar, black manganese and manganese-spar. This ore is chiefly worked for its gold and silver, all the zinc being lost by being either converted into cinder, or washed away. The red zinc ore is the principal source from which we obtain our supply of zinc, or spelter. This ore is extensively deposited in New Jersey and Pennsylvania, and is used for the manufacture of zinc, or spelter. There is a very large zinc works, at Bethlehem, Pa., and several large works in New Jersey. The red zinc ore is a compound of oxide of zinc, manganese and oxide of iron; its color is a brick-red, with a yellowish-tinge, like cinnabar. The calamine ore is a silicate of zinc; it is a dirty-yellow, or stone color; if pure, it consists of about one-half oxide of zinc; the other half is composed of carbonic-acid, siliceous iron, and other admixtures. This ore is very plenty, and is found, in heavy beds, in eastern

Pennsylvania; it is found in heavy veins, and may be looked for in all the lime-stone rock, from the most recent to the oldest formations.

Zinc is used, in its pure state, for sheet-zinc, and for coating sheet-iron, gas pipe, etc., with. To form galvanized iron—this is made by dipping the iron into a bath of molten zinc, and the iron comes out coated with zinc. Sheet-zinc is sometimes used for roofing buildings, but it should not be used for foundry roofs, as the steam from the sand corrodes it, and will soon eat it full of holes. Zinc is also extensively used with other metals, in forming alloys of brass, German-silver, hard solder, etc. (See ALLOYS.)

T I N .

Tin is a silvery-white colored metal, with a slight tint of yellow. Its fusing-point is 422° of Fahrenheit's scale. It is soft, and not very ductile, but is quite malleable, so that tin-foil, which is obtained by beating out the metal, is not more than one-thousandth of an inch in thickness. When quickly bent it utters a shrill sound called the *tin-cry*, which is caused by the destruction of cohesion and the crystals moving upon each other. When a bar of tin is rapidly bent backward and forward several times successively, it becomes so hot that it cannot be held in the hand. When rubbed, it exhales a peculiar odor. Tin does not oxidize rapidly at an ordinary temperature. Its tendency to crystallize is remarkable.

Tin, though one of the metals longest known to man, is found in but few localities. There are but two ores of tin known which are of any practical use. One of these is tin-stone, or peroxide of tin. The other is sulphuret of tin, or tin pyrites. No tin is manufactured

in the United States at present, although tin-stone is found in the New England States, and is said to have been discovered in Missouri. This, however, is doubtful. Tin-stone occurs chiefly in granite in heavy masses or lodes mixed with conglomerates of various rocks. It is also found in alluvial gravel as the result of the decomposition of the above rock, and is then called stream-tin. Tin-stone is of a variety of colors, white, gray, yellow, red, brown, and black. Its most striking feature is its weight. Tin pyrites are not very abundant, and cannot be considered an ore of tin. Their presence in the silver ores of the Southern gold region is so limited as to render the extraction of the metal unprofitable. This ore is of a gray or yellowish color, heavy, crystallized, and of a metallic lustre.

Tin is extensively used with other metals in forming alloys of pewter, brittania, brass, bell-metal, soft-solder, fusible metals, etc. Pure tin is commonly used for dyers' kettles. It is also sometimes employed for the bearings of locomotives, carriages, and other machinery. Common sheet-tin is formed by dipping sheet-iron in a bath of melted tin covered with oil, or with a mixture of oil and common resin. They come out thoroughly coated with tin. Tinned iron wire is similarly prepared. Cast-iron hollow-ware is tinned by heating the ware to redness, and putting molten tin into the pot or kettle intended to be tinned, and spreading it over the surface with a piece of cork. Sal-ammoniac or resin may be used as a flux. Pins made of brass wire are boiled with granulated tin, cream of tartar and water, which gives a bright white surface to the pins. Mirrors are silvered with an amalgam of tin and mercury. The process is as follows: Tin-foil is first spread evenly upon a marble table, and then the mercury is carefully poured over it. The two metals combine, forming a bright amalgam. A clean, dry plate of glass is then carefully pushed forward over the amalgam, so as to

carry the superfluous mercury before it, and also prevent the air from getting between the glass and the amalgam. Weights are then placed on the glass to cause the film to adhere more closely, and in twenty-four hours the glass is removed, and in three or four weeks is dry enough to be framed. This process of making mirrors is very injurious to health, and the workmen are short-lived. A paralysis sometimes attacks them within a few weeks after they enter the manufactory, and it is seldom that a man escapes for more than a year or two. The effects are similar to that of calomel. The men seem to dance instead of walk, and they cannot steady their nerves nor direct the motion of their hands; and in some cases they cannot digest their food. (See ALLOYS.)

L E A D .

Lead is a bluish-white metal; its fusing point is 620° of Fahrenheit's scale. It is remarkably flexible and soft, and will leave a black mark, on paper. It is poisonous, though not immediately, as bullets have been swallowed and then thrown off without any harm, except fright; its effects seem to accumulate in the system, and finally to manifest themselves in some disease. The sugar-of-lead has a sweet, pleasant taste, but is a virulent poison; its antidote is Epsom-salts.

Lead appears to have been known in the earliest ages of the world. The most common ore of lead, is galena, or sulphuret of lead; this ore has the lustre and color of polished metallic lead. It is always grey, without a shade of any other color, but its powder, when finely rubbed, is black. It is always found in a crystalline form, the crystals being cubes, often composed of square plates, and frequently so small as only to be

detected by the aid of a glass ; in other instances, the cubes, or the plate, which forms the cubes, are more than one inch square. Galena is very heavy, and equal to metallic iron, in specific gravity ; it is the heaviest of all metallic ores. Galena is very extensively distributed over the United States, and is found in almost every state in the Union ; the most extensive deposits are in the western states. It is extensively worked on the upper Mississippi and in Missouri. Galena, containing silver, is very extensively distributed over the whole gold region, but it is not generally in use. The difficulty of smelting this ore, profitably, appears to be in the way of its more general application. Lead is also obtained from the carbonate of lead, an ore of frequent occurrence, but it rarely forms a vein of itself. The phosphate of lead is also an ore from which metallic lead is obtained. Lead is reduced from its ores by roasting in a reverberatory furnace ; the sulphur burns and leaves the metal.

Lead is used, in its pure state, for pipe, bullets, sheet-lead, roofs, vessels for sulphuric acid, etc. ; it is also used, with other metals, in forming alloys of pewter, type metal, soft solder, fusible metals, etc. Ships were sheathed with lead and wood, from before the Christian era to 1450, after which wood was more commonly employed ; and in 1790 to 1800 copper sheathing became general. (See ALLOYS.)

N I C K E L.

Nickel is a white, brilliant metal ; it fuses at 2732° of Fahrenheit's scale ; it is ductile and malleable, acts upon the magnetic needle, and is itself capable of becoming a magnet. Its magnetism is more feeble than that of iron, and vanishes at a heat somewhat below redness. It does not oxidize by exposure to air, at

common temperatures, but when heated in the air it acquires various tints, like steel; at a red heat it becomes coated by a grey oxide.

There is very little nickel ore found in the United States, and the only mines that are worked, at the present time, in this country, are located in Eastern Pennsylvania; and from these mines the United States government receive their supply of this metal, for making the five-cent nickel coin, now in use. This metal is scarcely used, in its pure state, but is principally used together with copper, zinc, and other metals, in forming alloys, and these alloys are rendered the harder and whiter the more nickel they contain. The white copper of the Chinese, which is the same as our German-silver, is composed of three parts nickel, five parts copper, and two parts zinc; this alloy sometimes contains a little iron, and a small amount of that metal seems to improve the alloy. This metal is also extensively used for plating other metals, and for this purpose it is rapidly taking the place of silver. When plated on other metals, it has a silvery-whiteness, and receives a high polish, which lasts for years, and its hardness is almost equal to that of steel, which eminently fits it for the plating of mathematical and other delicate instruments. (See ALLOYS.)

A N T I M O N Y .

Antimony is of a silvery-white color, with beautiful laminated star-like crystalline structure, and is very brittle. Its fusing point is about 800° of Fahrenheit's scale, or at a dull red heat, and it is volatile at a white heat. Antimony is commonly found in the form of a sulphuret, which is very volatile, easily fused, and requires great caution in roasting. The sulphur cannot be entirely separated by roasting, and this causes the

roasted matter to have a dark-gray color. A mixture of sulphuret and protoxide, the more perfectly the desulphuration of the ore is performed, the more will the color approach to a faint yellow. Impure lead ore has this characteristic in common with antimony, but before roasting, it is not difficult to decide between antimony and lead.

Antimony was discovered by Basile Valentine, a monk of Germany, in the fifteenth century. It is said that to test its properties, he first fed it to the swine kept at the convent, and found that they thrived upon it. He then tried it upon his fellow-monks, but perceiving that they died in consequence, he forthwith named the new metal, in honor of this fact, *anti-moine* (*anti-monk*), whence our term *antimony* is derived.

Antimony expands on cooling. It is scarcely ever used alone, but is generally used with lead, tin and other metals in forming alloys. Antimony and tin mixed in equal proportions form a moderately hard, brittle and very brilliant alloy, capable of receiving an exquisite polish and not easily tarnished by exposure to the air. It has been manufactured into speculums for telescopes. (See ALLOYS.)

B I S M U T H .

Bismuth is a brittle, reddish-white metal. It fuses at 507° of Fahrenheit's scale; always crystallizes on cooling; is volatile at a high heat; transmits heat more slowly than most other metals, perhaps in consequence of its texture. This metal is seldom used alone for any useful purpose, but is employed for imparting fusibility to alloys of other metals. An alloy of three parts lead, two parts tin and five parts bismuth may be melted in boiling water or at a heat of 199° Fahrenheit, yet when these metals are melted separately, tin requires a heat of 442°, lead 620°, and bismuth 507°. (See ALLOYS.)

A R S E N I C .

Arsenic is a brittle, steel-gray metal. It very much resembles phosphorus in its general properties, and is therefore classified with it. If heated in the open air it gives off the odor of garlic, which is a test of arsenic. Arsenic is found in combination with iron ores and with cobalt. Arsenic anhydride, or white arsenic, that is sold in our drug stores, is made in Silesia by roasting arsenical iron ores at the bottom of a tower, above which are a series of rooms through which the vapors ascend and pass out at a chimney in the top, the arsenic burns forming arsenic oxide, which collects as a white powder on the walls and floors of the chambers above. Its removal is a work of great danger. The workmen are entirely enveloped in a leathern dress, and mask with glass eyes. They breathe through a moistened sponge, thus filtering the air of the fine particles of arsenic floating through it; yet in spite of all these precautions the workmen seldom live beyond forty years.

Arsenic is used in forming alloys with other metals. It is very volatile, and care must be taken to not inhale the gases from it, for they are a deadly poison, even worse than the arsenic itself. It is also used as a drug and for different chemical purposes. (See ALLOYS.)

M A N G A N E S E .

Manganese is a hard, brittle metal resembling cast-iron in its color and appearance. It requires the highest heat of the smith's forge to fuse it. It is very brittle and crystalline, and takes a beautiful polish.

Manganese is generally found in combination with iron; in fact there is scarcely an iron ore that does not contain more or less of this metal. There are only two principal ores of manganese that are of practical value;

they are the black manganese and the crystalline ores. There are other ores of manganese, but they are merely curiosities. The manganese ores are found in all the States along the Atlantic coast, near the lakes, and west of the Mississippi river. Vermont, Pennsylvania, Virginia and other States also furnish manganese.

Manganese is used in alloying iron to form speigeleisen iron. It is also used in the manufacture of steel. The black oxide is used with potassium chlorate for making oxygen gas for use in the chemical laboratory. It is also used in glass-works to clear or bleach the glass.

M A G N E S I U M .

Magnesium is a white metal; when pure, it has a silvery lustre and appearance; it is very light and flexible; a thin ribbon of the metal will take fire from an ignited match, when it will burn with a brilliant white light.

Magnesium is found in hornblende, meerschaum, soap-stone, serpentine and other rocks, and is very hard to obtain, and is very expensive.

Magnesium is used for a light in taking photographs at night; views of coal mines, interiors of dark churches, etc. Magnesium lanterns are much used for purposes of illumination; the metal is drawn into a thin ribbon, and is fed in front of a concave mirror (by means of clock-work) at the focus of which it burns.

A L U M I N U M .

Aluminum is a bright silver-white metal, it is only one-fourth as heavy as silver; it is ductile, malleable and tenacious; it receives its name from alum in which it occurs; it is also called the clay-metal.

Aluminum is found in slate-mica clay, and in all the clay rocks, and from these substances we obtain our entire supply. This metal is but very little used at present in the useful arts, but it must ultimately come into common use, for, next to oxygen and silicon, it is the most abundant element of the earth; every clay-bank is a mine of it, but the metal is very difficult to obtain, and can only be obtained by the galvanic process.

CHROMIUM.

Chromium is a metal prized only for its numerous brilliant colors. It is very rare, and is mainly found in chromic iron ore. The richest deposits of this ore in the world are found in this country, and the bare hills near Baltimore supply almost the whole world with chromic ore. Besides Baltimore, this ore is found in Pennsylvania, New Jersey, Vermont and Massachusetts. The color of this ore is a brownish-black like a hard brown iron ore.

COBALT.

Cobalt is a reddish-white metal, it is found in combination with arsenic. This metal is rare, and is little used in the useful arts of life. Its oxide is used for coloring glass, and gives the glass a beautiful blue color. It is also used in laundries to give a finished look to cambrics, linen, etc.

POTASSIUM.

Potassium is a silvery-white metal, it is soft enough to be spread with a knife, and light enough to float like cork on water. Its affinity for oxygen is so great that

it is always kept under the surface of naphtha which contains no oxygen. Potassium, when thrown on water, decomposes it and sets free one atom of hydrogen, and the heat is so great that the hydrogen catches fire and burns with some volatilized potassium, and gives the water the appearance of being on fire.

Potassium is manufactured from wood ashes, the ashes are first converted into lye, and then into potash, and from the potash the metal is obtained by distilling it in iron bottles at an intense heat, and the green vapors of potassium are condensed in receivers of naphtha. It is a difficult and dangerous process, for the vapor takes fire instantly on contact with air or water. This metal is but little used in its pure state, and is seldom made except for experimental purposes in the laboratory. Combined with other substances, it forms potash, pearlash, saleratus, saltpetre, and several other substances.

SODIUM.

Sodium is a silvery-white metal, and is very much like potassium. It is manufactured in a similar way to that metal, but is more easily managed. When thrown on water it rolls over its surface like a tiny silver ball; if the water be heated it bursts into a bright yellow blaze. This metal forms the principal part of common salt, and is found in all salt waters.



MINERALS AND GASES.

The following description of minerals and gases has been added to this work upon metals, that the foundry-man may more thoroughly understand the nature of the substances he has to deal with.

FUELS.

All the minerals which contain sufficient carbon to support combustion are called fuels, and as they contain carbon, hydrogen, or impurities in excess, they are designated anthracite coal, bituminous coal, brown coal, mineral charcoal, peat, etc. All these fuels have their respective peculiarities in burning. The anthracite coal is very hard, and contains but very little hydrogen. It burns with very little flames or smoke, and liberates a great amount of heat, but it must be burnt in a stove or furnace with a strong draft, so as to supply a large amount of oxygen from the air to unite with the carbon and hydrogen of the fuel.

Bituminous coal contains more hydrogen than the anthracite coal, and is more volatile and easily burnt. It burns with a bright flame, and throws off a black smoke which will deposit soot in our stove-pipes and

chimneys, and when this kind of coal is used in our stoves we must have large pipes and a good draft, or the pipe will be choked up in a short time with soot. This coal burns rapidly, and liberates more heat in the same time than the anthracite coal, but it is also consumed faster.

Brown coal is composed of about the same proportion of gases as the bituminous coal, and burns in about the same way, but it contains more mineral impurities, and leaves more ashes and cinders.

Mineral charcoal is generally burnt with bituminous coal.

Peat generally burns with a heavy smoke, and seems to smolder away rather than burn, and does not generate a very rapid and intense heat.

MINERAL CHARCOAL.

Mineral charcoal is frequently found in small veins mixed in with bituminous coal. These small veins are seldom more than one-fourth of an inch thick, and generally are a mere scale. They are generally found near the top of the coal vein, and only in the softer or poorer qualities of coal. More or less charcoal is found in all bituminous coal veins along the Ohio river, but in such small quantities as to render its separation from the coal impracticable. Mineral charcoal has never been found in this country in sufficiently large quantities to be of any practical value in the arts.

ANTHRACITE COAL.

Anthracite coal is the purest native mineral carbon of which we have any knowledge. It is found in great abundance in Eastern Pennsylvania, and is the princi-

pal fuel used in the Eastern and Middle States for heating purposes and for melting metals. This coal forms heavy veins, and masses in the metamorphic rocks of the eastern slope of the Alleghany mountains; but it is seldom found on the western slope of those mountains. This coal is very hard, and generally very black, but often of a bluish cast of great lustre. It breaks in irregular fragments, and the harder or best quality of it is not affected by the atmospheric air; but the softer coal from the upper veins will crumble if it is exposed to the air for a long time. The chemical composition of anthracite coal is almost entirely pure carbon, with a small percentage of hydrogen and a little ashes. From being so hard, it is more difficult to kindle than the bituminous coals, and requires the use of more kindling-wood to ignite it. When this coal is ignited in a considerable quantity, it creates an intense heat; but in small quantities it does not burn well, and requires a strong draft and a small pipe to support combustion in a small stove. This coal is the only fuel that is adapted in its native state for fuel in the blast-furnace. All others have to be charred or coked before using; and for this purpose it is extensively used in the States of Pennsylvania, New York, New Jersey, and Maryland. This coal is often called the *hard coal stone*.

BROWN COAL.

Brown coal is distributed more generally than is known. It is found both above and below the rocks of all ages. It is found in all the states of the Union, but it is never found in extensive layers, or veins, like the bituminous, or anthracite coal; but is deposited mostly in elliptical masses, or thin veins, which is seldom continuous. This coal is sometimes found in jet-black masses, and also of a brown color; we find it as hard

as anthracite, and so soft as to be crumbled into fine dust with the fingers; but it is characterized by its making a brown powder when pulverized, which may be more or less dark, but always shows its brown color. This coal always contains more impurities than either of the other coals, and makes more ashes, and is very sulphurous; and the ashes and sulphur combine in burning, and form clinkers on the grate-bars, causing trouble to the fireman, and making it more difficult to keep up the fire. All the coals that form a large amount of clinkers, are generally of the brown coal nature. Brown coal, that does not contain sufficient carbon to support combustion, is generally used for the manufacture of alum, either by burning or roasting it in large piles, and is considered the best material that can be obtained for that purpose. The brown coal is often called *lignite*.

BITUMINOUS COAL.

The name bituminous is applied to all mineral coal, that has never been properly defined, and usually means a soft, black coal, very rich in carbon and hydrogen, which burns with a dense, black smoke, at first. A natural and well-marked distinction between this and the anthracite coal, is its property of coking, that is, if it be heated to a red heat, it blazes, swells, and finally bakes together, forming a spongy mass, called coke; and if the fire is extinguished, at the proper time, by shutting off the supply of air, this soft, spongy mass forms the hard coke used for melting iron; but if the supply of air be not shut off, the coal burns to ashes. The coke made from bituminous coal, generally partakes of the impurities contained in the coal; and in making coke, for use in cupolas, or furnaces, coal should be selected that is free from sulphur, and other impurities that will injure iron. The Pittsburg and Yough-

iogheny river coal is of this quality, and is the principal coal used in the manufacture of coke, for foundry purposes, in this country. The only coal that is black, and makes a black powder, but does not coke, is anthracite; and all the coal, which makes a brown powder, but does not coke, is denominated brown coal. The bituminous coal is black, and makes a black powder, similar to the anthracite coal; but it is distinguished from it by possessing a more slaty structure, and its tendency to form slack when exposed to the air. This coal is generally very hard to break, across its fibrous structure, but may be split in direction of its fiber, the same as wood. Some of this coal breaks into beautiful cubical pieces, of which the Pittsburg vein shows many fine samples, and some veins break so fine as to form mere slack, as is the case with a vein found near Connellsville, Pennsylvania. This coal, when exposed to the air, will slack down almost as fast as burnt lime-stone. When exposed to the air, this coal is unfit for shipping, in its raw or pure state, on account of its tendency to break up fine and form slack; it is principally manufactured into coke, and forms what is known as Connellsville coke, which is the very best coke that can be obtained for melting iron in cupolas, for foundry use.

Bituminous coal is very easily lit, and after the first heavy smoke has been driven off, it burns with a bright vivid flame, similar to that of pine wood; and the anthracite coal usually burns with a faint blue flame, when first lit; but after it gets hot, the flame disappears altogether, except when supplied with a strong draft of air, when it turns to a faint yellow color. The chemical composition of bituminous coal differs from the anthracite only, in the larger amount of hydrogen it contains; this, in combination with carbon, forms bitumen, which can be extracted by distillation, in iron retorts, and from this circumstance is derived its name, bituminous coal.

Bituminous coal is found in almost all the States of the Union, and in vast deposits in the Mississippi Valley and the valleys of most all of its tributary streams, but it has not yet been worked to any extent along the Mississippi river; but along the Ohio river and through the western parts of Pennsylvania and Maryland this coal is very extensively worked. The quality of this coal varies in the different veins. West of the Alleghany mountains the Pittsburg vein is considered to be the best. This vein is of vast extent, and may be traced to a distance of one hundred miles from the city of Pittsburg, and it furnishes at every point where it has been opened the same kind of coal. This vein is named the Pittsburg vein, because Pittsburg is supposed to be located about the center of it. There are indications that some of the thick veins found in Maryland are a continuation of the Pittsburg vein. Should these indications prove true, this vein must extend through the Alleghany mountains and connect the Eastern and Western coal fields. The coal mined from the Pittsburg vein along the Youghiogheny river, a branch of the Monongahela river, is considered the finest bituminous coal mined in this country. It is of a beautiful jet black color, almost free from sulphur, and of a high lustre, frequently displaying the colors of the rainbow. This coal is soft and easily broken, but is not very liable to slack down when exposed to the air. It contains a great deal of carbon, and is considered a good coal for making gas, and it also makes a good, strong, pure coke, almost equal to the Connellsville coke, for melting iron. The Pittsburg vein does not furnish an equally beautiful coal throughout its extent; still it produces in every part a superior coal to other veins. The best coal of this vein is found within one hundred miles of Pittsburg, along the Monongahela river, while for one hundred miles along the Ohio river, below Pittsburg, it contains more sulphur, is softer, and leaves more ashes, and

is not near so good for coking. This vein varies in thickness; at and above Pittsburg it is seldom over seven feet, and generally from four to five feet, while below Pittsburg it is found in heavier veins, sometimes as thick as ten and fourteen feet. Coal from the vein above Pittsburg can always be sold for one or two cents per bushel more than coal from the vein below. The geological position of this coal forms a particular era, a separate period in the formation of rocks. It is not found in the old rocks, in granite or its associates, nor is it found in the transition or metamorphic rocks; yet in Virginia a bituminous coal is found, imbedded upon granite and surrounded by transition rocks of a different formation. This coal is not a true bituminous coal, but forms a link between it and the brown coal. This coal burns with a vivid flame and forms a soft coke that is easily crumbled and not fitted for melting metals. This coal, although a bitumen, is not a true bituminous coal of the secondary formation. It is useless to look for bituminous coal in the transition and metamorphic rocks on the eastern slope of the Alleghany mountains, or along the lakes, or in the Rocky mountains; but we may find brown or anthracite coal in these regions, but no true bituminous coal, for stoves and heating purposes. It does not make much difference whether we burn the brown or bituminous coal, but it makes a great difference in our cupolas or blast furnaces, because even the best kinds of brown coal generally contain a large amount of sulphur, which injures the iron. Even the best bituminous coal must be coked to drive off the hydrogen and part of the sulphur before it can be used for smelting metals. But the anthracite coal contains but little sulphur or hydrogen, and can be used in its native state for smelting metals from their ores, or for re-melting the metals. The bituminous coal is often called *soft stone coal*.

P E A T .

Peat, or turf, is not found to any extent in the United States, although some little is found on Long Island, N. Y., and at some few other places along the sea-coast; and in some of the Western States, peat is a black, carbonized material found in low, swampy ground. It is formed by plants which grow and sink on the very spot where they existed, and are converted into a kind of mineral charcoal by the action of the water and elements. Peat is cut from these swamps or bogs and dried and used as fuel in Ireland and some other countries; but in this country the peat-beds are too scarce, and mineral coal too abundant, to render the working of peat-beds profitable. Peat, when well charred, is equal to charcoal for the working of steel, and it is much used for that purpose where it can be procured.

C L A Y .

There are a great variety of clays. They are distinguished from each other by their different colors, and different grades of fusibility, etc. And they are distinguished from other earths by containing a certain amount of alumina, which imparts to clays their remarkable adhesiveness. All clays are plastic, and may be formed into various shapes; and they will retain the shape given them, and may be hardened by exposure to atmospheric air, or be solidified by fire to such a degree as to yield fire on being struck by a piece of steel. One of the common characteristics of all clays is their ready diffusibility in water, in which, although insoluble, they remain suspended longer than any other mineral. The more alumina they contain, the harder they are to dissolve in water, and the greater will be the

shrinkage and liability to crack when drying. All clays have a great affinity for moisture, and when dried in the air, or not burnt too hard, they will adhere to the tongue. Most all the clays are the residuum of decomposed rocks, and their great adhesiveness causes them to be found in beds of considerable extent, but always separated by a well-defined line from other matter. Its affinity for metallic oxides, and its combination with them, causes a great variation in its appearance, and by it combining with these different oxides is formed the different kinds of clay, such as the fire-clays, which are characterized by their resistance to fire; the potter clay, from its adaptation to the manufacture of pots and stone-ware; the China clay, from its adaptation to the manufacture of China-ware; while loam clays partake of the general characteristics of all the other more properly-defined clays.

FIRE-CLAY.

Fire-clay is a material that is found with veins of coal. It is generally below the coal formation, but it is sometimes found above or between the veins of coal. It is also sometimes found in iron ore districts, and the veins are frequently interspersed with an iron ore of the nature of clay. This clay breaks in the form of short slate, and falls into small, square grains, and is converted into plastic clay by the action of the atmosphere, which may be seen where the veins crop out. Fire-clay is of a gray or dirty yellow color. It is soft and easily broken. It can be mixed with or dissolved in water, and be converted into clay-wash or mortar. Fire-clay receives its name from its resistance to the action of fire, and it is extensively used in the manufacture of fire-bricks, and for lining blast-furnaces, cupolas, reverberatory furnaces, etc., for which purposes

it is admirably suited. This clay is found in almost all the States of the Union, and in great abundance in the States of Maryland, Pennsylvania, Ohio, and, in fact, all through the coal-fields. These veins of clay are much worked along the Alleghany and Ohio rivers, and all through the West. There is a very extensive fire-brick works at Ciotoville, on the Ohio river, and there is a very heavy vein of the first quality of fire-clay near Blairsville, Pennsylvania, from which large quantities of fire-bricks are manufactured. The veins of this clay often contain lime in admixture, which injures its fire-proof quality. Lime, if mixed with it, is always found at the top or bottom of the vein, and fire-brick made of clay from a limestone region will not stand the fire as well as clay from either above or below the coal veins. All fire-clay contains a little iron, which does not injure it for making fire-brick, but renders it useless for the manufacture of porcelain or stone-ware. pure clay is infusible in any heat, but if it contains a large percentage of iron or lime, it then becomes fusible, and in lining cupolas or other iron-furnaces with it, it soon takes up iron and becomes fusible at a high heat and is converted into a black slag. If the loam or clay obtained near a foundry is not sufficiently refractory for daubing the cupola, it may be made more refractory by mixing it with a pure or coarse sand. Some kinds of loam or clay must be mixed with one-half sand before they will resist the fire. The addition of a little salt also makes some of the clays more refractory.

L O A M .

Loam, or common clay, as it is more commonly called, is more generally diffused than fire-clay. It contains but little alumina, and is chiefly composed of silica, or

sand, with lime, iron, magnesia, mica, and a variety of other substances. Loam is more or less tenacious, and becomes more tenacious and adhesive the more it is worked; but it is generally very brittle when dried, and may be easily crumbled in the hand unless it be burned in an oven, when it becomes very hard, but brittle, and at a high heat it fuses and melts into a black, tough cinder or slag. Loam, like fire-clay, is rendered more fusible when united with iron, lime, or any metallic oxides. Common salt or saltpetre renders this clay more fusible, although they render some of the other clays less fusible. To the loam class belong all the blue, yellow, and red clays. When these clays contain any soluble salt, we can discover it by drying it, when the salt will form in small crystals on the outside and be visible in the form of a fine, white powder or flour, and by touching it to our tongue we can easily discover the kind of salt it contains; but if this class of clay contains any salt, it will not make a good daubing for a cupola or furnace, because it fuses too easily. Loam is used in the manufacture of bricks, tiles, and the coarser kind of potters' ware. The loam-clays are very abundant, and are found in all parts of the country. The best loams for standing the fire are generally found on hill-sides or on their summits. The yellow or red clays generally stand the fire better than the blue clays, and in all cases the clay that contains the most sharp or coarse sand stands the fire best, and before using loam for daubing in a cupola, it should be mixed with as much coarse sand as it will hold together.

POTTERS' CLAY.

Potters' clay, as it is called, is more compact, and more tenacious and smoother, than loam, and will receive a higher polish by rubbing it when moist with the

hand, which polish it will retain when dry. It takes the impression of the hand perfectly. Mixed with water, it forms a somewhat transparent paste. Potters' clay is always white or gray, and if it is good clay it will not alter its color when exposed to a red heat. It will resist the action of fire better than loam, and is infusible at the highest heat of a porcelain oven; and it becomes very hard and not very brittle by the action of fire. When this clay is produced by the decomposition of feldspar, it has a gritty feeling, and is called *Kaolin*, which is the principal material used in the manufacture of porcelain. Considerable practical experience is required in the selection of clay to make first-class ware. If the clay changes its color on being exposed to a white heat, it is not good clay, and the ware made from it will be brittle, or will not endure being heated in the oven sufficient to harden it without melting or alteration of the form. Good potters' clay is extensively distributed throughout the country. It generally lays below the loam-clays, and is thought to have been formed by the decomposition of slate rock. This clay would make a better daubing for cupolas than loam, but it is more difficult to obtain, and in many cases it is more expensive than fire-clay; but where it can be procured cheap it should be used in preference to loam.

C H I N A C L A Y .

China clay, or porcelain clay, is infusible in the most intense heat of any ordinary fire, and retains its white color, and does not shrink so much as the potters' clay. It is formed in nature by the decomposition of feldspar and granitic rocks. It feels more gritty and crumbles easier than the potters' clay, and is not so diffusible in water. This clay is found in abundance in all the Eastern and Southern States of a superior quality for

the manufacture of china and porcelain ware ; but it is seldom found in the Western States, or where the granitic or feldspar rocks are not found. This clay is more expensive to work than potters' clay, but the ware made from it is stronger and whiter, and is sold at a higher price. All our white ware is made of this clay.

SOAPSTONE.

Soapstone is of a grayish-white, and often of a greenish color. It is found in all the States of the Union, and in great abundance on the eastern slope of the Alleghany mountains, and in all the coal fields. It is used in the manufacture of the French chalk, used by tailors. It is an excellent fire-proof material, and when finely ground it is used for dusting the faces of molds in stove foundries, to impart a smooth and sharp face to the casting and prevent the sand from adhering to it. For this purpose it is sometimes used alone or in its pure state, but when used in its pure state it gives the castings a very white color, which is not desirable, and for this reason it is generally mixed with hard coal and charcoal finely pulverized. Soapstone constitutes the principal fire-proof ingredient of all foundry blacking or return faceon, and is also used in fire-clay and in the manufacture of fire-brick.

ASBESTOS.

Asbestos, or Mountain Wood, is a mineral that is found on the eastern side of the Alleghany mountains. It is a fibrous mineral and often appears as if composed of fibres. Its fibre very much resembles the fibre of wood, and it is easily split like wood in the direction of its fibre. It is very elastic and malleable, has a silky

lustre, and feels as soft as silk. It is of different colors, white, green and brown.

Asbestos is characterized by its resistance to the influence of heat, and the poor qualities are used as fire-proof material for lining furnaces, and the superior qualities are sometimes woven into lamp-wick, etc. It will resist the influence of heat better than any of the fire-clays in use at the present time. It will even resist the action of chemicals used in forming the compound used in porcelaining hollow-ware. It is found in great abundance in some of the Eastern States, and at different points all along the eastern slope of the Alleghany mountains. This material can in many places be procured at less cost than fire-clay, and I do not see why it has not come into general use for the lining of furnaces. If ground and combined with fire-clay, it might make a superior fire-brick to any in use.

The *Gazetta Industriale* gives the following account of an interesting exhibition of asbestos recently held in Rome, and at which this singular material was represented in all its multifarious forms and conditions, from the crude state as mined, to the most valuable industrial preparations. Thus, among this curious variety there were samples of thread made from the mineral, which were stronger than the best English cotton; cloth, from coarse bagging to a fabric as fine as linen, and paper for writing, printing and sheathing buildings, and pasteboard. The Italian asbestos paper costs about forty cents per pound, and is found especially serviceable for important documents which it is desired to preserve from fire. To illustrate the fire-proof qualities of the pasteboard, a case made therefrom was filled with ordinary paper, and another case of pasteboard, not containing asbestos, but in every other respect exactly similar, was likewise filled, and both were thrown into a fire. In the space of some five minutes the unprepared pasteboard box and its contents were wholly

consumed, while to that period the asbestos box retained its original appearance and condition unchanged, and without receiving the slightest injury.

S A N D S .

Sand, like clay, is very abundant, and there is a great variety of kinds, as the sharp-sand, the fire-sand, the loam-sand, etc. The sharp-sand is a hard, granular substance, very sharp and gritty. It consists principally of quartz rock, which appears to have been worn off and decomposed by friction. It is found in the form of strata, and in loose alluvial deposits of immense extent in all parts of the country. In beds or banks of this sand we frequently find well-preserved pebbles of rock crystal, which is most common along the sea-shore and on the shores of the lakes. Sharp-sand is very extensively used in the preparation of lime-mortar, in the manufacture of glass, in making water-filters, and, where fire-sand cannot be obtained, it is used for mixing with fire-clay and other clays used in daubing and repairing cupolas and furnaces ; and it is the principal sand used in making dry-sand cores and in dry-sand molding. For these purposes it is mixed with a little flour, resin or molasses-water, to make it more adhesive and hard when dry.

Fire-sand is also a sharp, coarse, open sand, and is generally of a bright yellow color. This sand is characterized by its resistance to fire, and is principally used in daubing and repairing cupolas and furnaces, and for mixing with clays to make mortar for laying up fire-brick and other furnace linings.

Loam-sand is found in great abundance in all parts of the country. It contains a small portion of alumina, and is of a more clayey nature than either of the other sands. It is the sand principally used in foundries for

molding The fine-grained or finer quality is used for green-sand molding and light work, and the coarser sands are used for heavy work in green-sands, and some of them will make a good dry-sand core or mold without the addition of flour or resin. This grade is principally used in making pipes, which are generally molded on end and skim-dried before casting.

Gravel is a coarse sand that is mixed with stones or boulders of all sizes. This sand or gravel is found in the beds of rivers and streams, and often in large deposits or hills. In this sand we find valuable metallic substances, such as gold, platinum, copper, iron, etc., which are mixed with the sand and often imbedded in the boulders. From this sand we obtain our entire supply of platinum, and from it all the gold found in California and all the gold diggings, were formerly obtained, and from it a great deal is obtained at the present time; but in California, at the present time, the largest amounts of gold are obtained by crushing the quartz rock.

C A L C I U M .

Calcium is found in gypsum, in the bones of our body, in the bones of animals and in lime-stone rock. Caustic, or quicklime, is a calcium oxide; it is obtained by heating lime-stone, in large kilns, with coal, or other fuel, and burning off the carbonic oxide, which leaves the calcium oxide, or common lime, used for mortar, plaster, etc. Burnt lime-stone is a strong alkali, and will corrode the flesh; it has a great affinity for water, and will absorb it from the air, and be expanded by it to several times its original size, with the evolution of much heat. Whitewash is the milk of lime, or lime dissolved in water. Water-lime contains a little clay, and will harden under water. Concrete is a cement of

coarse gravel and water lime ; it is of great durability. Mortar is made of lime, sand and water, mixed in different proportions. If mortar is exposed to the air, it becomes hard, but if it is protected from the air it will remain without hardening for many years ; it is said that mortar has been found in the pyramids of Egypt that was still in its soft state. Lime is also used for a fertilizer ; in this case, it is spread over the land, and it rapidly decomposes all vegetable matter, and thus forms a manure for the plants ; it also sets free the alkalies that are combined with the soil, and becomes itself a manure. The calcium carbonates constitute not only lime-stone, but also marl, marble, chalk, corals, shells, etc. In lime-stone regions, the water sometimes dissolves the calcium of the rock, and as it trickles down into caverns it will form stalactites, which depend from the top of the caverns, and stalagmites, that rise from the floor ; these are found in great abundance in the mammoth cave, in Kentucky. Marble is a white, crystallized lime-stone. Chalk, or marl, is a porous kind of lime-stone, formed by beds of shells ; it is not so compact as the common lime-stone. Whiting is ground chalk. Plaster-of-Paris is made from gypsum, a beautiful white rock, which is so soft that it can be cut with a knife into rings, vases, etc. ; when it is heated, it loses its water, and is then ground into a fine powder ; when used, it is made into a thin paste, with water ; it first swells up, and then immediately hardens into a solid mass ; it will even harden under water ; it is used in copying statues and medals, forming molds for the fusible metals, etc. The plaster used as a fertilizer, is unburnt gypsum, which has been ground to a powder ; its action as a fertilizer is somewhat like that of lime.

M A R B L E .

Marble is a species of lime-stone, and is termed, by chemists, a calcium carbonate; it differs from lime-stone, in being more sound and compact, and generally of a more bright, clear color. All lime-stone that can be quarried in large blocks, without fissures and stratification, may be termed marble. Marble has a very fine grain, and is adapted to receiving and retaining a fine polish; it is of a soft nature, and can easily be cut into slabs, or carved into any desired shape; the best quality of it seems to harden in the air, and is almost as enduring as granite. White marble has a clear, pure color, and not a dirty-grey, like the common lime-stone, and the value of variegated marble is determined by the clearness of its colors. Marbles of all kinds are found in great abundance in the eastern and southern states, and some very fine varieties of variegated, or breccia marble, is found in Maryland. Very little marble is found in the western states, until we get to the Rocky mountains. Marble spalls are used as a flux in blast furnaces, and also in cupolas, in place of common limestone; when used in a blast furnace they generally make a superior iron to the common lime-stone flux, but on account of expense, their use is restricted to certain localities where marble is abundant.

L I T H O G R A P H I C S T O N E .

Lithographic stone is a fine-grained limestone, still finer than marble. It receives the name lithographic stone because it is used by engravers for engraving upon. This stone is distinguished from marble or common limestone in being of a more slaty structure, and breaking into thin slabs. This stone is not found in the

United States of a sufficiently good quality to be used in the art of engraving, and at the present time we receive our entire supply of it from Germany, where a superior quality is found in great abundance. But this stone is rapidly going out of use for engraving, and wood, copper and steel being substituted for it on account of being engraved with more certainty, and in many cases producing better work.

PUMMEY-STONE.

PummeY, or rotten-stone, is a soft mineral of an earthy fracture and very fine texture. Its color is generally a yellow-gray or dirty-white. It does not adhere to the tongue like clay, and is easily pulverized. It is extensively used for polishing iron and wood, and for rubbing down paints. It is found in abundance in this country.

SILICON.

Silicon, or silex, is found in combination with oxygen, and is commonly called quartz. This element is very abundant, and probably comprises nearly one-half of the earth's crust. When pure it is transparent and colorless, as in crystal rock. Silicon is principally used in the manufacture of glass.

BARIUM.

Barium is a white mineral noted for its weight, and is often termed heavy spar. The term barium is derived from the Greek, and means heavy. This mineral is largely used for adulterating white-lead.

E M E R Y .

There is an abundance of emery, or emery-producing rock, found in the United States. An excellent emery, which is extensively used in the manufacture of emery-wheels, for polishing and grinding metals, etc., is procured by pulverizing the harder varieties of dolomite, or whetstone rock. The hardest and best quality of emery is procured from korund, a material similar to the dolomites of the gold regions. These materials are found in great abundance in the Southern States, and in all the Western gold regions, and at the present time a large amount of emery is produced from these rocks in the United States, which is principally used in the manufacture of emery-wheels, emery-paper, etc.

G A R N E T S .

Garnet is a very hard material of a dark-red or brown color. It is found in large quantities in different parts of the United States, and particularly in the gold regions. It is usually found imbedded in and scattered through rock in small crystals or grains. The finer qualities of garnets are generally used in the manufacture of jewelry, and the less brilliant specimens are pulverized and used as emery ; and they make a superior quality of emery to either dolomite or korund ; but they are more expensive than either of these substances, and for that reason are but little used for emery. Yet there is an abundance of the poorer qualities of them found in the Southern States, and a profitable business might be done in converting them into emery.

A M B E R .

Amber is a solid, resinous mineral of various shades of color, but mostly of a brownish yellow, resembling common resin; in fact it is a fossil resin, which has exuded in some past age of the world's history from trees. Now extinct, it is sometimes found containing various insects perfectly preserved, which were, without doubt, entangled in the mass while it was yet soft. The most characteristic feature of amber is its fine aromatic odor, which it emits when thrown on hot coals. It is found in the vicinity of layers of brown coal, and is often cast up by the sea, and is found in large quantities along the shores of the Baltic. This mineral is not found to any extent in this country. The finer specimens of it are used for ornaments, mouth-pieces, necklaces, buttons, etc., and it is the principle ingredient of all fine carriage varnish, and the poor qualities are used in the manufacture of common resin, for which purpose it is the most valuable mineral that can be found.

A L U M - S L A T E .

Alum-slate is the material commonly used in the manufacture of crystallized alum. It is a dark colored slate resembling coal-slate, but the best alum-slates are of a more clayey nature than the coal-slate, and often contains so much bituminous matter as to render it combustible if piled up in large masses and kindled, in this slate. The dark color indicates the presence of bitumen or carbon, and yellow spots or streaks indicate the presence of sulphur. The sulphurous or pyrites slates are considered the best for making alum, for in obtaining the alum from these slates, sulphuric acid is used to dissolve them, and if the slate contains consider-

able sulphur, the acid may be formed by adding a solution of ammonium sulphate. Alum-slates are found in great abundance in all parts of the United States, and an excellent quality is found in all the western coal fields, from which large quantities of crystallized alum is manufactured. Alum is much used by dyers in dying woolen and cotton goods; it unites with the coloring matter and binds it to the fibres of the cloth. Alum-slate is used by potters and ware manufacturers for glazing and giving the ware a fine finish. This is done by simply throwing the slate into the oven, where it is volatilized by the heat, and is decomposed by the hot clay and forms a coating over its surface.

Alum stone is a hard volcanic rock, from which Roman alum is manufactured in Italy. It is not found to any extent in the United States, and is not used for the manufacture of alum in this country.

ASPHALTUM.

Asphaltum is a black, resinous material that exudes from the earth in a fluid state along with water near salt or brine springs. It is similar to petroleum oil when it first comes from the earth, but becomes hard like pitch or resin when exposed to the air for some time. It burns with a dense, black smoke, and is sometimes used in the manufacture of lampblack; it is much used in paving streets, and the famous promenades of the boulevards in Paris is made with it; it forms a natural cement for laying stone, and was used for that purpose in building the walls of Babylon, for which it was obtained from the fountain of Is, on the banks of the river Euphrates. It was a prominent ingredient of the Greek fire, which was formerly used by the nations of the East in their naval wars.

Asphaltum is found in immense quantities in dif-

ferent parts of the world. There is a lake of it on the island of Trinidad that is nearly three miles in circumference, and a large lake of it has lately been found in California; it is also found in Canada in large quantities.

SULPHUR.

Sulphur is a bright yellow substance, hard and very brittle, is a non-conductor of heat and crackles when grasped with a warm hand. It is found native in volcanic regions, and is mined at Mount *Ætna* in large quantities. It is found united with metals, forming the sulphides known as iron-pyrites, copper-pyrites, galena blende, cinnabar, etc. Combined with oxygen, it forms sulphates of silver, gypsum, heavy spar, etc. In commerce sulphur is sold as brimstone, which is formed by melting the sulphur and running it into molds; it is also sold as flower of sulphur.

Pure sulphur is not found in the United States in sufficient quantities to be of practical value. The chief sources from which we obtain our supply is from the sulphurets of metals, which we possess in great abundance. Iron-pyrites contain a large percentage of sulphur, and from it sulphur is obtained by simple distillation, in iron or fire-clay retorts, when it yields the greater part of the sulphur it contains; the remainder, sulphuret of iron, is easily converted into copperas. Sulphur cannot be dissolved in water, and hence is tasteless; it can only be dissolved in oil of turpentine and benzole. When it is melted and heated to a high heat, it changes to a thick dark-colored liquid resembling molasses. If this is poured into cold water, it becomes elastic like india-rubber. In this form it is used for taking impressions of statues, medals, coin, etc. After a time, the sulphur regains its hardness as well as its brittleness, if exposed to the action of the air. Sulphur

is extensively used in the manufacture of matches and gunpowder, but it is principally used in the manufacture of sulphuric acids. The burning of sulphur forms a very suffocating gas, which is very poisonous, and will extinguish combustion; it is used for bleaching silk, straw and woollen goods. Chlorine turns them yellow, but the fumes of sulphur unites with the coloring matter and forms a colorless compound; its action is, therefore, very different from that of chlorine. When white flannels that have been bleached with sulphur are washed in strong soap suds, they turn yellow, because the alkali of the soap unites with the sulphuric oxide used in bleaching the flannel, and thus sets free the original color. If sulphur is burned in a barrel before filling it with new cider, it will prevent fermentation.

Sulphur will unite with almost all the metals, forming a sulphate of the metal. It has a great affinity for metallic silver, and will unite with it even in its solid state. It will unite with iron while in the molten state and cause the iron to be both hard and brittle.

PHOSPHORUS.

Phosphorus is a very light, flexible substance, soft enough to be spread with a knife. It burns at all temperatures above 35°F., and emits a feeble light; it melts at 110°F. It should be handled with the utmost care, and always cut and kept under water, except when wanted for use. It is a deadly poison, and its vapor produces horrible ulcerations on the bodies and bones of the workmen who use it. Its burns are deep and dangerous; even its vapor from matches should be avoided. Phosphorus glows in the dark as if it were on fire. It was called the son of Satan by the old alchemists.

Phosphorus exists in small quantities in fish, in shells,

bones and rocks. It is so necessary to the operation of the brain, that it is said: "No phosphorus, no brains." We obtain our entire supply of phosphorus from the bones of animals, by a process of distillation with carbon, and condense it under water. It is principally used in the manufacture of matches; it is also a little used in forming alloys with metals, and to form solutions for plating metals by the electrotype processes. It is found in combination with iron, in iron ore, and it will injure iron more, and is harder to remove from it, than any other substance.

PETROLEUM.

Petroleum oil is obtained from the *petra* rock, a soft, sandy rock beneath the surface of the earth. This oil is probably the product of the distillation of organic matter which has been deposited at some time beneath the present surface. It is principally found beneath the coal-measures, and some little has been found outside the coal-measures; but these are generally very small deposits, and the supply of oil soon gives out. The distillation of this oil from the organic matter must take place at a much greater depth than that at which the oil is now found, for it would naturally rise through the fissures of the rocks and gather in the crevices or pockets of the rocks above where it was formed, and where the rocks were very soft, or where there was large fissures in or between them the oil came up through to the surface of the earth and collected upon the surface of springs and pools of water; and in this way it was first discovered in the western part of Pennsylvania, along the Alleghany river above Pittsburg. Wells were then put down, and large quantities of oil were found at a depth of fifty feet, and in some cases less than fifty feet. The supply of oil in

these wells was soon exhausted, and new wells were put down along the oil belt, which is a belt about two miles wide running down toward Pittsburg, and in this belt all the oil is found. The oil territory in West Virginia, below Pittsburg, is supposed to be a continuation of this belt. which probably dips below the Ohio river and rises again near Petroleum, West Virginia. The oil first obtained on this belt near Oil City was at a depth of fifty feet; but the oil belt runs deeper as it gets near Pittsburg, and it has been followed down, and at the present time there is very little oil obtained at a less depth than twelve or fourteen hundred feet. This oil, when first pumped, is of a black, greasy color, and is generally accompanied with salt water. The crude oil from the well is purified by distillation by heat. That which is evaporated and passes over into the crevices at the lowest temperature is called naphtha, or benzole, and as the heat is increased there passes off next the kerosene oil, which we burn in our lamps for illuminating, and lastly, lubricating oil. The kerosene is next deodorized and decolorized by the use of sulphuric acid and other chemicals which are stirred in the oil, after which it is redistilled and comes out pure and colorless as we buy it for use in our lamps. This oil, when pure and entirely free from naphtha or benzole, is no more explosive than water; but when united with naphtha or benzole, it forms an explosive and dangerous compound. I have tried to use this oil in a cupola for softening iron, and as a flux and fuel. With this view I first introduced it at the tuyeres without any blast. This proved a failure. The oil made a big blaze, but seemed to deaden the coke and put out the fire. I next tried oil and super-heated steam together, but this was worse than the oil alone, and would put out the fire altogether in a short time. I then tried steam and oil with a blast. This worked better, but was no better than the blast without the oil and steam. I then tried

the oil and blast together, but found that nothing was gained by using the oil in any way, or in either large or small quantities.

B O R O N .

Boron is found in nature in combination with oxygen as boracic acid. It is abundantly found in volcanic regions. Small lakes of it are found in Thibet, and also in California. Boron is the source from which we obtain our supply of borax. This is obtained by boiling and evaporating the boracic acid in lead pans heated by steam, when the water is evaporated and the borax collected.

I O D I N E .

Iodine is made from the ashes of sea-weed, and is found in sea-water and in some mineral springs. It is named from its beautiful, violet-colored vapor. It is much used in medicine.

C H L O R I N E .

Chlorine is named from its green color. It has a peculiarly disagreeable odor. It is chiefly found in salt, of which it forms sixty per cent. Its gas produces a suffocating cough which can be relieved by breathing ammonia or ether. Chlorine has such a powerful affinity for hydrogen, that it will even attract it out of moist organic bodies. It is used for bleaching muslins, linen, paper-rags, etc. It is a powerful disinfectant, and is used in sick rooms and hospitals where persons have died of contagious diseases. It is also combined with other materials, forming acids, etc.

B R O M I N E .

Bromine is a deep-red liquid with the general properties of chlorine. It has a very bad odor, and its gas is a rank poison. It is found in sea-water. It is principally used in photography and medicine.

F L U O R I N E .

Fluorine is the only element that has no affinity for oxygen. It is found in fluor-spar rock. It unites with hydrogen, forming hydro-fluoric acid, noted for its corrosive action on glass.

S A L T .

Salt is a mineral that is found in a solid form, as rock salt, and in solution with water in the ocean and brine springs or wells. Rock salt is found in different parts of the Union, and is principally used for salting fish, corned beef, pork, etc., in barrels. The principal source from which we obtain our supply of salt, for general use, is by evaporating sea-water or the salt brine from springs or wells. Natural salt-water springs are found in the State of New York, and there is an extensive lake of very strong brine in Utah Territory. Salt is manufactured in the Eastern States principally from sea-water and brine springs, and in the Western States from brine obtained from artesian wells. Large amounts of salt are manufactured from these wells along the Ohio river and other rivers that flow into it. There are some very extensive salt works at Pomeroy and Middleport, on the Ohio river, that furnish large quantities of salt for the Southern market. Salt is a substance that

is absolutely necessary to sustain human life and the lives of the higher orders of animals. It does not seem to enter into the composition of our flesh, but assists in the digestion of our food. One of the most severe and cruel punishments inflicted upon criminals in China is to deprive them of salt. This causes, at first, a most indescribable longing and anxiety, and finally a painful death.

OXYGEN.

Oxygen is the most abundant of all the elements. It comprises by weight one-fifth of the air, eight-ninths of the water, three-fourths of all animal bodies, and about one-half of the crust of the earth. It has no odor, color or taste. It is a vigorous supporter of combustion. Its union with substance is called oxidation, and the product an oxide. It combines with every element except fluorine. From some of its compounds it can be set free by the stroke of a hammer, while from others it can be liberated only by the most powerful means. Oxygen is the principal destructive agent of the atmosphere, as it comprises one-fifth of the common air, it is ever present and waiting. Fruit and vegetables wither and rot, and we say that they are decaying, but it is only the oxygen corroding them and breaking up their chemical structure and forming new and unpleasant compounds. If we cut or bruise our flesh, we soon feel the destructive action of the oxygen at work upon the quivering nerves, and we apply a strip of court-plaster or bind it up with a rag to prevent the action of the oxygen upon it, and give nature an opportunity to heal the wound. An animal dies, and the oxygen at once begins to remove the body. If we wish to preserve the body, we exclude the air from it or cover it with salt to prevent the corrosive action of the

oxygen upon it. Our teeth decay because of the action of the oxygen upon them, and the dentist saves them by filling any break in the enamel with a cement which has very little affinity for oxygen, or with gold, or platinum. The water in our cisterns becomes foul and putrid, and we uncover it and the oxygen rushes in and picks up each atom of impurity and sinks to the bottom; and the thick sediment we find at the bottom of our cisterns and rain-barrels, is but the ashes of combustion of these impurities caused by union with oxygen. We take air into our lungs; here the blood absorbs the oxygen from it and bears it to all parts of the body, depositing it wherever it is needed. Ladened with this life-giving element, the vital fluid sweeps tingling through every artery and vein, combines with a portion of the food thrown into the circulation from the stomach, breaks up every worn-out tissue, burns up the muscles and sets free their force until at last it comes back through the veins dark and thick with the products of the combustion. The cinders of the fire within us, the human body, is like a furnace in which fuel is burnt, and the chemical action is precisely like that in any other furnace, for we take food into our stomach and the air or oxygen into our lungs, and the union of the oxygen with the food in the stomach forms a combustion and produces heat, and our bodies are kept warm by the constant fire within us. When there is plenty of food in our stomach, the oxygen burns that, but if there is no food in our stomach the destructive oxygen must still unite with something, and so it combines with the flesh and it first burns up the fat and we grow poor, then the muscles, and we grow weak, next the brain, and we become crazed, and in this way we are burnt up as a candle burns out to the darkness, hence we see why we fire up our human furnace with three square meals a day. All the muscles of our body are burnt up in about eighty days of ordinary labor.

Our heart works day and night, and it is burnt out in about forty days, so that we have a new set of muscles every eighty days, and a new heart every forty days. If the stomach is supplied with food, our muscles and heart is replaced as fast as they are burnt up, but if no food is supplied, the oxygen burns up the muscles and the heart, and we die. Thus the destructive oxygen wastes us away constantly from birth to death, and yet it is essential to our existence. Why is this? simply because we live only as we die, and the moment we cease dying we cease living. We can perform no labor except by the wearing away of the muscles; no thought can be evolved except by the wearing away of the brain, hence we see the necessity for food to supply the constant wearing away of the system, and for sleep to give nature time to repair the losses of the day. We lay down at night feeling tired and exhausted, and arise in the morning feeling refreshed. This is simply because nature has repaired the losses of the muscles while we slept. Nature has no idlers in this world, each atom has its use. Oxygen, so destructive in its action, is essential, that every waste compound may be broken up and its components returned to the common stock for use in forming new compounds. In performing this general task its uses are most important and necessary, for were it not for oxygen, nothing in nature would decay. The earth would be strewed with dead bodies of animals and vegetable matter. To avoid this, nature has provided oxygen as the common scavenger, and it is ever present in every dark cellar, every dark street and alley, and in every part of the world ready to remove by decay every waste substance upon the face of the earth. A leaf falls, and the oxygen forthwith commences its destruction; a pile of rubbish, the dead body of an animal, decayed vegetables, etc., are all removed by the destructive oxygen.

HYDROGEN.

Hydrogen is not so abundant as some of the other elements; it is chiefly found in water, of which it forms one-ninth part, by weight. This gas may be obtained from water by dropping small pieces of zinc into a bottle partly filled with sulphuric acid, diluted with water, as in forming muriate of zinc for soldering; but in this case the mouth of the bottle is closed with a cork, and the gas collected through a small tube. The hydrogen prepared in this manner has a disagreeable odor, which is caused by the impurities in the zinc used; but this gas when pure is like oxygen, colorless, transparent and odorless. It has more diffusive power than any of the other elements, and in attempts made to liquify the gas, by compression, it leaked through the pores of a thick iron cylinder in which it was compressed. It is not poisonous, yet it will destroy life, or combustion, by shutting out the life sustainer, oxygen. Hydrogen is the lightest of all the gases, being only one-fourteenth as heavy as common air, and for this reason it has been used for filling balloons, but as coal gas is also very light, and can be obtained much cheaper than hydrogen, and for filling balloons it has generally taken the place of hydrogen, yet the small rubber toy balloons are all filled with diluted hydrogen.

If we put a lighted candle into a jar of hydrogen the candle will be extinguished and the gas will take fire and burn with a feeble flame. One atom of the oxygen of the air unites with two atoms of hydrogen, and the product of the combustion is water; if the oxygen is supplied rapidly the flame will be stronger. Hydrogen in itself is not explosive, but if two parts, by measure, is mixed with five parts of common air it will explode violently when ignited, and when making this gas, or when making muriate of zinc for

soldering, care should be taken to keep fire away from it, for the gas may take fire and run down into the bottle and explode it. A hydrogen flame gives little light but great heat, and when united with oxygen, according to its chemical affinity, it possesses great force when set free.

NITROGEN.

Nitrogen is a very abundant element; it forms four-fifths of the atmosphere, and is the principal element in ammonia, nitric acid, flesh, and in such vegetables as the mushroom, cabbage, horse-radish, etc., it constitutes the principal part of many valuable medicines, such as quinine, morphine, and also of the potent poisons, prussic acid and strychnine. Nitrogen in its pure state will neither burn nor permit anything else to burn; a candle will not burn in it, and a person cannot breathe it alone and live, yet when united with one-fifth oxygen it is both a supporter of combustion and life. Thus in these two elements we have the two most important elements of the world, and without either of them we could not exist, for nitrogen alone is sluggish, and when undiluted we could not exist in it a moment, and pure oxygen is too active. If the air was undiluted oxygen we would be excited to a pitch of which we can scarcely dream, and we would sweep through life's feverish burning course in a few days, and the world would be swept with a fierce conflagration. Thus we see that separately either of these elements, that constitute the air, would kill us, oxygen by its radical action and nitrogen by lack of action.

Nitrogen has only but very little affinity for any other elements, and although it will unite with many of them, yet the instability of its compounds is very curious. For instance, it will unite with iodine, but a heavy step on

the floor, or a stroke of a hammer, will set it free. Four-fifths of the air we breathe is nitrogen, and one-fifth is oxygen. One-fifth of our flesh is nitrogen, yet none of it comes from the air we breathe, for the nitrogen comes out of our lungs the same as it went in, but a portion of the oxygen contained in the air remains in our bodies and performs the wonderful work of digesting our food, stimulating and giving us life. The nitrogen contained in our flesh is obtained from the lean meat and vegetables we eat. Plants breathe the air through the leaves—their lungs—yet they do not appropriate any of the nitrogen contained in the air, in this way, but obtain their supply from the ammonia and nitric acid which their roots absorb from the soil; and from these plants, animals and mankind receive their entire supply of nitrogen in the flesh; but even after obtaining it in this way, we hold it very loosely, and the tendency of our flesh to decompose is largely owing to the instability of the nitrogen it contains. Nitrogen enters our fires with oxygen, the oxygen unites with the fuel and supports combustion, but the nitrogen, having no chemical affinity for the fuel, passes through the fire and out of the chimney. Even in a furnace, where iron melts instantly like wax, nitrogen is not consumed, but comes forth as pure and unaltered as when it entered. It is so sluggish and dull that it will not unite directly with any organic substance, and even the most intense heat of the furnace will not make it more active.

Nitrogen is too inert for our use, and oxygen is too active; yet, by combining them as in nature, we have the golden mean—the oxygen quickens the nitrogen, and the nitrogen retards the oxygen, and it quietly unites with the fuel in our stoves and gives us heat,—with the oil in our lamps, and gives us light. It corrodes our bodies and gives us strength; cleanses the air and keeps it fresh and invigorating. It works all

around us, and even within us, yet with such delicacy and quietness that we never notice it or think of it, unless we see it with the eye of science.

The chief compound of nitrogen is nitric acid. This acid is found in nature combined with sodium or potassium, and it is formed in the atmosphere in small quantities by electricity in time of thunder-storm, and is washed to the earth by the rain, and absorbed by the roots of vegetables and plants.

Nitric acid is colorless, and as clear as water when pure, but as sold in our drug stores it commonly has a golden tint, caused by the presence of a lower oxide of nitrogen produced by the decomposing action of the light. It is a very corrosive and poisonous liquid, and was formerly called aqua-fortis, or strong water. Its strength is next to sulphuric acid. It stains wood or the skin a bright yellow. It has been obtained in brilliant, transparent crystals, but they soon decompose from the action of the air. This acid gives up its oxygen readily, and is a powerful oxidizing agent.

Nitric acid is chiefly employed in dyeing wool yellow, and by surgeons for burning the proud flesh in old sores. It dissolves all of the metals except platinum and its kindred metals, and when combined with chloric acid it forms the usual solvent of gold. It is used for etching the beautiful designs seen on the blades of swords, razors, etc. The process of doing this is very simple. The surface of the blade is first covered with a varnish that resists the action of the acid upon it; the desired figure is then sketched in the varnish with a very fine-pointed tool; the acid is then poured on, and it oxidizes the metal in the delicate lines thus laid bare.

Nitrous oxide is one of the gases of nitrogen. It is a colorless, transparent gas, with a faintly-sweetish taste and smell. It is a supporter of combustion as well as oxygen. If breathed for a short time, it pro-

duces a peculiar kind of intoxication and laughter, and for this it is often called laughing-gas; but the effect soon passes off. If taken for a long time its effect is similar to ether or laudanum, and causes insensibility; and it is much used for surgical and dental operations.

Nitric oxide is another gas of nitrogen. It is a colorless gas, and has a very disagreeable odor and a great affinity for oxygen. The ammonia, or hartshorn-gas, is also one of the nitrogen gases. This gas is prepared by heating sal-ammoniac with lime in a retort, and collecting the gas. Water heated to 60° Fahrenheit will absorb seven hundred times its own bulk of this gas; and this compound constitutes the common hartshorn solution sold in drug-stores. The solution, when as strong as this, will produce a blister, and must therefore be very much reduced with water before being tasted or touched to the skin. It is a strong alkali. Ammonia receives its name from the temple of Jupiter Ammon, near which sal-ammoniac, one of its compounds, was once manufactured; and it receives the name hartshorn from being at one time made in England from the horns of the hart, a wild animal.

C A R B O N .

Carbon is one of the most abundant elements in nature. It composes nearly one-half of the entire vegetable kingdom, and it forms a prominent constituent of coral marble lime-stone and of most all the rocks. It exists in three distinct forms, viz.: the diamond graphite and amorphous carbon.

The graphite carbon is also called kish and black-lead, because on paper it makes a shining mark like lead. The graphite is supposed to be of vegetable origin. It is found native in almost all the States of the Union, and in large quantities in New York, Vermont

and Massachusetts. It is chiefly used in the manufacture of lead-pencils. For this purpose an alloy is made of graphite, antimony and sulphur. The proportion of each ingredient determines the hardness of the pencil. This alloy is melted and cast into blocks, which are sawed into thin slips, as seen in the common lead-pencils. The hard and gritty specks that we sometimes find in pencils are caused by the antimony not being thoroughly mixed with the graphite and sulphur. For drawing-pencils, and all the best pencils, this alloy is not used; but they are made of pure graphite, which is powdered and subjected to such enormous pressure that the particles are brought near enough together to form a solid mass, when the pressure is removed. This block is then sawed into small strips, which are fitted into cylinders of cedar-wood. Graphite is also used as British lustre, carboret of iron, stove-polish, etc., which are employed for blacking stoves and protecting iron from rusting. It is also used for mixing with clay to make black-lead crucibles, which are the most refractory crucibles known. Gas-carbon is found in the interior of the retorts used for making gas from bituminous coal. It has a metallic lustre, and is so hard as to scratch glass. It is sometimes used in cupolas as a fuel and flux in the melting of iron, and is said to make iron more fluid and hold its life longer.

Charcoal carbon is made by burning wood in a retort or oven, or in piles so covered over with turf as to prevent free access of air. The volatile gases, water, etc., are driven off, and the carbon left behind. The charcoal thus made will form about three-fourths of the bulk of the wood, and one-fourth of its weight. Charcoal for gunpowder and for medicinal purposes is made from willow or poplar wood, and the best charcoal for common use is made from maple wood.

Charcoal is the most unchangeable of all the elements, so that even in the charcoal we can trace all the deli-

cate structure of the wood from which it was made. It is insoluble in any ordinary liquid ; no alkali will eat it, and none of the acids, except nitric acid, corrode it ; neither air nor moisture affect it. Wheat has been found in the ruins of Herculaneum that was charred 1800 years ago, and yet the kernels are as perfect as if grown last harvest. The ground ends of posts are rendered more durable by charring. Some charred posts were dug up not long since in the bed of the river Thames, which were placed there by the ancient Britons to oppose the passage of Julius Cæsar and his army. A cubic inch of fine charcoal is so full of minute pores that it is said to have one hundred feet of surface. These small pores absorb gases by capillary attraction to an almost incredible extent. One inch of charcoal will take up ninety times its bulk of ammonia. Foul water filtered through charcoal loses its impurities ; and beer, by filtering through charcoal, parts not only with its color, but with its bitter taste, and comes out clear and transparent as water. Pans of burning charcoal soon purify and sweeten the offensive air of a hospital, and the fumes of charcoal will cause death in a close room.

Animal charcoal or bone-black, is made by charring bones in closed retorts. It is largely used by sugar refiners for filtering brown sugar, to make white or loaf sugar. In doing this, the brown sugar is dissolved in water, and filtered through twilled cotton to remove the coarse impurities, and then through a deep layer of bone-black, and all the impurities are removed ; it comes out a colorless solution, and is next evaporated in vacuum pans in which it is boiled at so low a temperature as to avoid all danger of burning it. When sufficiently concentrated, the liquid is removed, and set aside to drain and crystallize, and the drainings constitute syrup or sugar-house molasses, and the crystals constitute loaf or granulated sugar. Common vinegar

filtered through bone-black, becomes the white vinegar used by pickle manufacturers. Bone-black is also used for blacking, mixed with hydrate-sulphuric acid and oil, it forms the basis of all shoe blacking.

Diamonds are said to be pure carbon, crystallized; they are the hardest of all known substances, and will scratch all other minerals and gems, and can be cut only by their own dust. They are infusible, but will burn at a high rate of temperature. Diamonds are found in Southern Africa, Brazil, Borneo, and some few have been found in Georgia and North Carolina, but our principal supply of diamonds come from Brazil. It is said that this country, in 1858, furnished 125,000 carats of diamonds. The weight of a carat is equal to four grains of Troy weight. The term carat is derived from the name of a bean, which, when dried, was formerly used by the diamond merchants in India for weighing diamonds. Diamonds are usually found in semi-transparent round pebbles enclosed in a thin brownish opaque crust, which, when broken, reveals the brilliant gem within. They are of various tints, though often colorless and perfectly transparent. The colorless diamonds are the most valuable, and from their resemblance to a drop of clear spring water, they are called diamonds of the first water. Diamonds are exceedingly brittle, and valuable gems have been broken by simply falling on the floor. Although the diamond is simply pure carbon, yet it has never been made by any chemical process. Nothing definite is known concerning the original formation of the diamond. Paste diamonds are now made in Europe, which are so perfect an imitation of the real diamond, that only experts can distinguish them. Diamonds are ground and polished by means of their own powder; the gem to be polished is fitted to the end of a stick or handle, and is pressed down firmly against the face of a rapidly revolving wheel covered with diamond powder and oil, this, by its

friction, gradually grinds off the exposed edge, and forms what is termed a *facet* of the gem. The diamond is not only used for ornaments, but it is also used for many mechanical uses, such as cutting glass, rock-drills, etc.

The amorphous carbon, or carbon having no determinate form, is far more abundant than either the graphite or diamond forms of carbon; it comprises soot, lampblack, charcoals, mineral coal, coke, peat, muck, and all the various carbonic gasses, etc.

Soot is unburnt carbon which passes off from a candle or fire, when there is not enough oxygen present to combine with all the carbon of the fuel, and form a perfect combustion, the carbon therefore comes away in flakes, and passes off in the air or lodges in the chimney of the house. Much more soot will be deposited in the chimney when green wood or bituminous coal is used for fuel, than when hard coal or coke is used, for the moisture in the wood absorbs much of the heat of the fire, and the carbon in the bituminous coal is more volatile and easily set free than in the hard coal or coke, and it is permitted to pass off unconsumed. The flakes of unconsumed carbon or soot often collect in the chimney, and after a large quantity has collected, it catches fire, and burns out with a great roar and flame.

Lampblack is made by imperfectly burning pitch or tar; this creates a dense cloud of smoke, which is conducted into a room lined with sacking, where it condenses, and the soot or lampblack collects on the sacking. Lampblack is largely used in the manufacture of paints; it is mixed with clay to form black drawing crayons. It has peculiar properties which fit it for printers' ink, nothing in nature could supply its place for this purpose. No matter how finely it is pulverized, it retains its dead black color, the minutest particle is as black as the largest mass; it is insoluble in all liquids; it never decays; the paper may decay or we

may even burn it, and yet, in its ashes, we can trace the form of the printed letters. The ancients used an ink said to be composed of gum-water and lampblack, and manuscripts have been exhumed from the ruins of Herculaneum, which are perfectly legible. The printers' ink in use at the present time is composed of lampblack and linseed oil.

Carbon constitutes the principal part of all mineral coals, these coals were formed at an early period of the world's history, called the Carboniferous Age. In this age the earth was pervaded by a genial tropical climate, the air was more dense and rich with vegetable food than now; the earth itself was a swamp, moist and hot, in which simple ferns towered into large trees, and the plants, like those we trample under foot to-day, grew to the height of lofty trees; in these swamps accumulated a vast deposit of leaves and fallen trunks, which, under the water, gradually changed to charcoal. In the course of time the earth settled at various points, and floods poured in from the seas, bringing with them sand, pebbles and clay, filling up the depression. The pressure of these deposits, together with the internal heat of the earth, expelled the gases from the vegetable deposits and converted them into mineral coal. Where the pressure was great the hard or anthracite coal was formed, and where the pressure was light the soft or bituminous coal was formed, and where there was little or no pressure, or where it was not flooded by the sea, there vegetable deposits were converted into peat or muck. In some parts of the world these deposits or beds of peat are of vast extent—one-tenth of Ireland is covered by them.

Coke is made from bituminous coal by heating it in retorts or ovens and burning off the tar, water and volatile gases; after these impurities have been burnt away the fire is put out so as to retain the carbon in the coke. Coke is much used in the manufacture and

working of iron, and also for fuel for locomotives, engines, stoves, blacksmiths' forges, etc.

Carbon is found in a great many contrary forms; it is soft enough for the pencil, and hard enough to cut glass; clear and brilliant it gleams and flashes in the diadem of a king; black and opaque, it expresses thoughts on the printed page. In graphite it resists the fiercest heat; in lampblack it will take fire spontaneously; as oil we burn it in our lamps and it gives us light; as coal or wood we burn it in our stoves and it gives us heat; we burn it in our locomotives and it gives us power; as coal or wood it readily unites with oxygen and gives us heat; as graphite we spread as stove polish on our iron-ware to prevent the corrosive action of the oxygen upon the iron; it constitutes the valuable element of coal, wood and all burning oils or gases. Carbon thus supplies our wants in a great many different ways.

The carbonic gases are almost as abundant as the carbonic solids. These gases are all known under the general name of carbonic oxides or carbonic acid gas, yet the proportions they contain of the different elements make a great difference in the nature of the gas. This gas is found abundantly in a large number of carbonates, such as limestone, marble, etc., and it forms nearly one-half of their weight, and almost one-seventh of the earth's crust. This gas is formed in the air, by the air being breathed into our lungs, and by burning carbon in our stoves, by light, decay, fermentation and all the various forms of combustion, and it is taken from the air by plants, vegetables, trees, etc., which breathe the air into the leaves (their lungs), and retain the carbonic acid to build up their structure and set free the pure oxygen, in this way the air is purified of this dangerous gas, were it not for these plants the air would become so full of it that we could not live in it, for three per cent. of this gas in the air acts as a

poison by putting us to sleep and preventing the proper action of the oxygen upon our blood. Air of this proportion of oxygen and carbonic acid will sometimes be formed or accumulate in old wells, cellars, mines, etc., where many incautious persons have lost their lives by it. Cellars that contain this gas can generally be purified by ventilation, and it can be driven out of deep wells or mines by a blast of fresh air or by lowering pans of slacked lime or burning coals into them. Shallow wells may be purified by throwing a bundle of burning straw into them.

This gas is abundantly formed by burning charcoal, and if burned in an open furnace, in a closed room, it will cause death by putting us into a sleep from which we never awake. In France it is not unusual to commit suicide by burning a pan of charcoal in a closed room. If persons who attempt suicide in this way are found before life is extinct, they may be revived by bringing them into the fresh air and dashing cold water upon their face.

This dangerous gas is formed in deep mines by the burning of *fire-damp*, a colorless, odorless gas, which is formed in low, marshy ground and in coal mines. When controlled it burns with a yellowish flame, but when burnt uncontrolled it explodes like gunpowder, forming dense volumes of carbonic acid gas, which is called by the miners, *choke damp*. Both of these gases are dreaded by the miners, the *fire-damp* from its explosive nature, and the *choke-damp* from its suffocating nature. Either of these gases will destroy life. As carbonic acid gas is formed by breathing air into our lungs, the proper ventilation of our dwellings is a matter of great importance, that we may not have to breathe the same air over again. The languor and sleepiness we feel when in a crowded assembly is caused by the re-breathing of air; the idea of drinking in, at every breath, air that perhaps has just left the lungs of an-

other person, is most disgusting. We shun impurity in every form, we dislike to wear the clothes of another, or to eat from the same plate, and yet we crowd into theatres and halls with them and inhale their polluted breath.

Carbonic oxide gas is formed by burning fuels in our stoves or oil in our lamps; it is a colorless gas, with very little odor or smell, and burns with a pale blue flame; combined with oxygen it forms carbonic acid gas. Carbonic oxide gas is a deadly poison, and escaping from coal-fires in a close room, has often produced death. The anthracite coal will form more of this gas than any other fuel, and when burned in sleeping rooms, care should always be taken to have the rooms well ventilated. The carbonic oxide gas is similar to the fire-damp of the coal mines.

Coal gas is a carbonic gas made from bituminous coal, by heating it in iron or clay retorts and collecting the gas, which is then passed through coils of pipe to condense it and separate the tar, and is next passed through a coil of pipe to cool it, and through water and slacked lime to purify it; it then passes into the receiver for use. This gas is the most valuable of the carbonic gases; it is largely used for illuminating purposes, as well as for heating purposes. This gas is used by most all of our large steel works for melting and heating the steel, for this purpose it is more economical than coal or coke, and can be used to better advantage. Coal gas has a very bad smell, and is very poisonous when inhaled into the lungs.

A T M O S P H E R E .

The atmosphere, or air we breathe, is composed of four-fifths of nitrogen, one-fifth of oxygen, and a very small amount of carbonic acid gas. This latter is not

naturally in the air, but is formed in our lungs as we breathe the pure air, and if we were shut up in a close room, with no supply of fresh air, we would so convert all the air in the room into carbonic acid gas by breathing, that we could not live in it. The carbonic acid of the air is heavier than common air, and when thrown into the air in large quantities, it sinks to the bottom, and for this reason we raise our beds from the floor, so that we may be in the purer air; but when the amount of carbonic acid is small, or when we open the door or window of our bed-rooms in the morning, the purer air rushes in and unites with the heavy carbonic acid, according to the law of the diffusion of gases, so that the air near the floor becomes as pure as that near the ceiling. By this law of diffusion the air becomes the same everywhere. Samples of it have been analyzed from every conceivable place—from polar and torrid regions, from prairies and mountain tops—and the result is almost exactly the same everywhere; yet when the air is confined to close rooms, mines, etc., it unites with the impurities with which it comes in contact, and forms disagreeable and often dangerous compounds, such as fire-damp, choke-damp, etc. But all these dangerous compounds disappear when a plentiful supply of air is admitted into the mines, for they soon unite with the pure air, according to the law of diffusion of gases, and the impurities causing the fire-damp or choke-damp are thrown out of the compound. The gases of the air do not form a chemical compound, but a mere mechanical mixture, and for this reason they readily unite with other substances, forming these dangerous compounds; and for the same reason they are readily thrown out of the compound when diffused through a larger amount of air. Were the gases of the air to unite chemically, and the substances which constitute its impurities to unite chemically, it would not be so easily purified of its impurities, but would grow more and more impure,

until we could not breathe it and live. The gases of the air are distinct and separate, as so many grains of corn and wheat mingled in a measure, and each of these gases has its separate use and mission. The use of the oxygen is to quicken the nitrogen and make it more active, and the use of the nitrogen is to retard the oxygen and make it less active, so that we may have it under control for our use, as shown under the head of OXYGEN.

The carbonic acid of the air bears the same relation to vegetables that oxygen does to animal life. The leaf of the plant is the lungs of the plant. Through its millions of little pores or mouths, it drinks in the air, which again escapes, leaving part of the carbonic acid behind, the same as when we breathe the air into our lungs, it again escapes, leaving part of its oxygen behind to quicken our blood into life and sustain the life within us. In the leaf of the plant the carbonic acid inhaled into it at night is decomposed in the daytime by the sunbeams, and the carbon applied to building up the plant, and the oxygen returned to the air for our use. Plants thus breathe out oxygen as we breathe out carbonic acid. We furnish vegetables with air for their use, and they in turn supply us. There is thus a mutual dependence between the animal and the vegetable world. Each relies upon the other. Deprived of plants, we would soon exhaust the oxygen from the air, supply its place with carbonic acid, and die, while they, removed from the animal world, would soon exhaust the carbonic acid and die. We pollute the air, while they purify it by each tiny leaf and spire of grass, imbibing our foul breath and returning it to us pure and fresh. This interchange is so exactly balanced that the proportion of carbonic acid and of oxygen in the open air never varies. The vegetable or plant which contains the carbon thus rinsed from the atmosphere by the action of the sunbeam is also full of potential force, and

by its energy and action builds up the plant, and the force of the sunbeam becomes latent in the vegetable structure. The sun shining on our meadows causes the grass to grow. If the grass be eaten by an animal, the same amount of force will be liberated as it receives from the sun. Thus the grass represents, not alone so much carbon, oxygen, and hydrogen, but also a certain amount of sun-force which gives the animal strength, for in the process of digestion the force stored in the grass is transferred to the animal, and gives it muscles, and produces motion, heat, etc. Thus by digestion the animal robs the grass or grain of its force and returns to the earth the hydrogen, oxygen, nitrogen and carbon of its construction, to be again used in the formation of new compounds. As water is very abundant in the earth, so is it abundant in the air as vapor. Were the air perfectly dry, our flesh would become shriveled, all vegetable matter would wither; the rivers and streams that flow to the ocean would be dried up, for all these are fed by the moisture in the air, which rises from the ocean and streams as vapor and falls upon the earth as rain, dew, snow, or hail, and in this way the vapor, or moisture of the atmosphere supplies the earth with water.

W A T E R .

The composition of water is proved by analysis, by separating the compound into its elements, and by uniting the elements to produce the water. Water is an extinguisher of combustion, yet when thrown on the hot coals in small amounts it is decomposed, and the hydrogen burns with a pale flame, while the oxygen unites with the fuel and increases the combustion. Thus in a fire: if the fire-engines throw on too little water, it may be decomposed and add to the fury of

the flames. Water thrown on a fire by means of hose is scattered into detached fragments, and is heated and decomposed by the flames before it reaches the fire, and for this reason it is less available for quenching a fire than water thrown directly on the fire by means of buckets.

Water is a very abundant substance. It composes four-fifths of our flesh and blood, and of the flesh and blood of all animals, so that man has been said to be made of twelve pounds of solid matter, wet up with six pails of water. All plumpness of the flesh and fairness of the cheek is given by the water in our system, and a few ounces of water and a little carbon constitute the principal chemical difference between the round, rosy face of sixteen, and the wrinkled face of sixty. To supply the constant demand of our system for water, each adult in active exercise needs about three pints per day, or over one-half a ton a year. In fish and water animals the supply of water is still more abundant. Some of our fish are little more than organized water. In an analysis made by Professor Agassiz, of a sunfish caught off the coast of Massachusetts, which weighed thirty pounds, only one-half ounce of dried flesh was obtained, the balance of the fish being water.

The lower order of fish, or those to which belong the jelly-fish, medusa, etc., are said to be composed of only ten parts in a thousand of solid matter. Water is also a very abundant substance in the vegetable world. Wood is composed of six parts of charcoal and forty parts of water, with a little mineral matter which comprises the ashes. Potatoes are composed of seventy-five parts of water; turnips are ninety parts water; carrots are eighty-three parts water; cabbages are ninety-two parts water; cucumbers are ninety-seven parts water; watermelons are ninety-eight parts water, and all other vegetables contain water in the same proportion.

Mineral water is water that is or has been combined

with solid or mineral matter, and when combined it is chemically known as *hydrates*; thus the images which the Italian makes from plaster of Paris are the hydrates of plaster of Paris, because they contain nearly one pound of water to every four pounds of plaster. One-third of the weight of all ordinary soil, clay, soft rocks, etc., are water, and most all water contains more or less mineral matter, and when it contains much mineral matter, the taste of the water is not generally agreeable, there being but a few kinds which taste well and produce a pleasant sensation when drank. When water contains more mineral matter than is consistent to our sense of taste, it is called acidulated water. Water which is of a crystalline purity and has an agreeable and refreshing taste, generally contains pure carbonic acid gas. Water possessing the smell and taste of rotten eggs contains sulphur, and this peculiar smell is produced by sulphuretted hydrogen gas, generated from soluble metallic sulphurets. If the quantity of sulphuretted hydrogen is not too large the taste of this water is not repulsive, but the smell is decidedly so. Water of this description possesses remarkable medical properties, and springs or wells of it are famous as resorts for invalids. When water has a cool, refreshing taste, but has an additional earthy after-taste, it contains either sulphate of lime, gypsum or carbonate of lime. Dissolved limestone or magnesia causes water to have a bitter taste, resembling that of Epsom salt, which is not very unpleasant if the quantity of metal dissolved is not too large. Solutions of iron impart to water a taste like black ink, which is very disagreeable if there is much of it in the water. Potash and soda give water a very soft, sweetish taste, if contained in small quantities; but when contained in large quantities it forms a strong alkali brine, which is bitter to the taste and very injurious. The salts of potash or soda appear chiefly as chlorides in mineral water, producing the

peculiar taste of common salt. When the sulphates of these metals are present in water, it has a bitter taste, very much resembling the magnesia water, but stronger and more repulsive. Some waters contain acids and clay in solution, which are thus held by the acids; these waters are always of a milky-white color, and have a slightly sour taste. All acids contain more or less water; strong nitric acid contains the most; but if the water was removed it would destroy the acid itself. If we expel the water from sulphuric acid it will lose its acid properties, and we can handle it without injury to our flesh. If we evaporate the water from blue vitriol, it will lose its color and become white like flour, and a few drops of water will restore the blue color. If we expel the water from crystallized borax or alum by heating they will puff up, and the transparent crystals will dry into a white incoherent mass; and many other salts part with their water of crystallization when exposed to the air, and crumble into a powder.

Pure water has no taste, color or smell, and is perfectly adapted to be the solvent of solids, for it becomes at pleasure sweet, sour, salt, bitter, nauseous and even poisonous. Rain water, caught after the air has been thoroughly cleansed by a thunder storm, or a long continuous rain, is the purest natural water known; it is tasteless, yet its want of taste makes it seem to us very ill-flavored, since we have become accustomed to the taste of mineral impurities in hard water, they have become to our taste sweetness and pleasantness.

Saline waters are even more impregnated with foreign matter than mineral water is; they are very repulsive to the taste, and generally have a strong medicinal effect. Saline water may contain but one ingredient, or it may contain many different kinds of mineral matter, the latter is the most common. The saline waters are those which contain a considerable amount of chloride of sodium, as does sea-water, and all the

brines from salt-wells or springs. Most of these brines also contain sulphates in large amounts, which give the water a very bitter taste. Sea-water belongs to the saline waters; the most abundant mineral in this water is common salt, yet it contains traces of every substance soluble in water, which has been washed into the sea from the surface of the earth during all the ages of the past. The proportion of these substances contained in the water are being daily increased, as the water which evaporates from the surface is comparatively pure, containing only a mere trace of a few of the lighter substances; this vapor is carried over the earth in clouds, and deposited upon it in the shape of rain, and again washed into the ocean, carrying with it more mineral substances. This operation has been going on for ages, so that the saline matter contained in the water of the ocean at the present time is about one-half ounce to the pound of water, and this amount will be slowly increased as the water evaporates; yet all the mineral matter washed into the ocean does not remain in solution, but is slowly deposited upon the bottom and along the coasts. In small lakes which have no outlet, and are not moved by the tide, the water becomes stronger from the saline deposits than in the ocean. Salt Lake, in Utah Territory, has become a strong brine, nearly one-third of its whole weight consisting of saline matter, but this condition would soon disappear if an outlet could be provided. River water generally contains more or less organic matter, as well as mineral matter, and for this reason it is often unfitted for drinking or for cooking purposes; but running water has in itself a certain purifying power, owing to the air which it holds in solution, so that in time it will become more pure still. In order to avoid danger of sickness from using river water for cooking or drinking, it should be filtered through charcoal and sand before using.

As water strains through the soil or gravel into our

wells, it dissolves more or less of the various mineral matters characteristic of the locality ; this matter, the principal part of which is lime, salt and magnesia, unites with the water, and forms what we term hard water. If the water is obtained from a limestone locality, it will contain a large percentage of lime, and when boiled in our tea kettles, it produces a coating of fur on the sides and bottom of the kettle, and if this water is used continually, the coating of fur will be increased and gradually turned into a heavy solid limestone scale. When we put soap in this water, when either hot or cold, it curdles from uniting with the lime, and forms calcium oxide or lime soap, which is insoluble in water and floats upon the surface of it, but if a large amount of soap is used it will curdle and sink to the bottom of the water. Magnesia has about the same effect on water when dissolved in it as limesone has. A very minute amount of salt combined with these waters makes them still harder.

As the world of water is inhabited, it has its atmosphere, similar to the earth's atmosphere ; for water is composed of eight-ninths of oxygen and one-ninth of hydrogen by weight, so that the inhabitants of the world of water have an abundance of oxygen, even more than we have. Yet we could not live in the world of water, simply because the oxygen is combined with the hydrogen, and our lungs are not adapted to breathing them together, or to separate the oxygen from the hydrogen. The water fills our lungs, and we drown. Fish inhale oxygen from the water through the fine silky filaments of their gills. When a fish is drawn out of water, these fine filaments soon dry up and the fish is unable to breathe, although it has a more plentiful supply of atmosphere than it is accustomed to enjoy. Thus the fish dies in our atmosphere simply because it is too dry for its lungs, and we die in the water simply because its atmosphere is too wet for our lungs.

Water contracts on cooling until it gets down to 39° Fahrenheit; then it slowly expands until it reaches its freezing point, when it congeals and its crystals suddenly shoot out at angles to each other; and the harder it freezes the more it expands, until it congeals into ice. Although ice is only congealed water, yet it is lighter than water and swims on top of the water; and as the surface of our rivers and ponds freezes, the ice forms a blanket or covering over their surface and protects them from the cold atmosphere, and keeps the finny inhabitants of the water warm and comfortable till spring; then the warm sun soon dissolves it, or the spring flood floats it south to melt under a hotter sun. Were it not that ice is lighter than water, it would not swim on top and form a cover over the surface of the water, but would sink to the bottom as fast as it was formed, and our rivers and ponds would freeze solid to the bottom, killing all the fish and aquatic plants; and even the sun of a hot summer could not melt such an immense mass of ice. Water seems a very yielding substance, but if we fall a short distance on to the water, and light flat on our belly, the pain in our stomach will convince us that water is not so yielding a substance as we thought it was.

Water is one of the most unyielding substances in nature, and when confined in the hydraulic ram a few gallons may be made to lift tons of solid weight. An excess of water will destroy life by drowning, and a lack of water will cause a lingering and painful death from thirst. Thus we see the different effects of water.

The uses of water are very diverse, for its properties fit it for a wonderful variety of uses in nature; it is the common carrier of the world, and also the common scavenger of the world. Upon the bosom of the seas, lakes and rivers float the ships that conduct the commerce of the world, which directs the flow of trade and wealth, decides the founding of cities and advancement

of nations ; upon its bosom floats the iron-clad navies of the world, which protect its commerce and dictate and uphold the rights of nations ; it propels the water-wheel, and thus becomes the grand motive-power of manufacture ; it washes down the mountain side, bearing with it mineral matter to fertilize the soil ; it comes in the clouds as rain and lays the dust in our streets, and sprinkles our gardens and puts new life into our vegetables and plants ; it moistens our lips and quenches our thirst on a hot day, and flows through our body as blood, giving us fresh life and vigor

COMBUSTION.

Combustion is the destruction of substances by uniting with oxygen, which generally causes heat and light, but in many cases the heat generated is so light as not to be noticed by us, as is the case when wood rots or iron rusts, and in all cases of decay, fermentation, etc. The only difference between the combustion of the substances that decay, and the substance that is destroyed by fire, is that the oxygen unites with those destroyed by fire more rapidly and generates more heat ; and as we wish to cause more or less heat by the combustion of fuel in our stoves or furnaces, we raise the stack or chimney higher that we may have a good draft of air through the fire and supply oxygen to the fuel rapidly, which makes the combustion rapid and the heat more intense.

All our fuels, wood, coal, oil, etc., consist mainly of carbon, and in order to ignite these fuels we elevate the heat of a small portion to the point of rapid union with oxygen, and that part in burning will give off heat enough to support the combustion of the rest. Thus when making a fire we take paper or shavings, which expose a large surface to the action of oxygen,

and by igniting these with a match they soon raise the required temperature to start the combustion of the chips or fine kindling-wood, and the heat from the wood will soon ignite the coal, and the oxygen of the air unites with the carbon of the coal, and continues the combustion until the carbon is exhausted. But if after the fuel has been ignited we close the damper of the stove, and shut off the supply of oxygen, the carbon ceases to burn, and the coal smolders in the grate, and finally the fire goes out altogether. Carbon, even when ignited and in a state of combustion, will not remain so unless it is well supplied with oxygen.

Carbon is most wisely fitted for fuel, since the product of its combustion is a gas; were it a solid our fires would be choked, and we would have to remove as much ashes from our stove as we supplied fuel; and in the case of a candle or lamp it would be still more annoying, as the solid product would fall around our rooms; and were it fusible like lead or zinc, it would melt and run down through the grate and out upon our floors in a liquid mass. The flame from our fuel is burning gas, and a candle or lamp is a small gas-works, for their flame is the same as that of a gas-burner. In a candle we have a little cupful of tallow or wax, melted by the heat of the flame above it, and the cup that holds it is formed by the ascending currents of cool air, which supplies the flame with oxygen, keeping the outside of the candle hard; but should the wind blow the flame downward, this hard rim on the outside is melted, and the liquid tallow or wax runs down the side of the candle. The melted tallow or wax in this little cup is carried up through the small tubes of the wick by capillary attraction to the flame, and by the heat of the flame is converted into a gas, and becomes the flame in this way; the flame is supported as long as there is a sufficient amount of tallow or wax to supply the gas.

The flame of a candle is always hollow, and at the

center of the flame, near the wick, the gas is formed by the heat of the flame around it. Part of this gas may be conducted out of the flame by a small pipe, and burned at a little distance from the candle. The flame is hollow because there is no oxygen at its center, for the gas floats outward from the wick as it is formed, and comes in contact with the oxygen of the air and burns on the outside while more gas is formed inside. The flame is blue at the bottom, because there is so much oxygen at that point that the hydrogen and oxygen burn together and give little light; and the flame near the top gets red because the carbon passes up from the wick and unites with the oxygen, and if too much carbon is supplied for the supply of oxygen, the carbon passes off at the top of the flame in a black smoke. The wick of a candle does not burn, but is merely charred by the heat of the flame, because the flame drives off the oxygen from it, and protects it. If we blow out a candle quickly the gas still passes off, and the candle may be immediately re-lit with an ignited match held at some distance from the wick; but if we let the wick get cold, we must bring the flame of the match in contact with the wick before we can ignite it. The tapering form of the flame is due to the currents of air that sweep up from all sides toward it. The candle must be snuffed because the flame follows the wick down as the tallow is consumed, and the long, charred wick would cool the blaze below the igniting point of the carbon and oxygen, and the carbonic gas would only be partly consumed. We do not snuff our lamps, because the oil is in a liquid state, and it does not require the heat of the flame to melt it before it can be drawn up the wick, and the flame does not pass down the wick and char it. A lamp with a glass chimney produces a steadier and brighter flame than a lamp without a chimney would, because it confines the hot air and makes a draft of heated oxygen to feed the

flame; and we use the flat wick because it presents more surface to the action of the oxygen. When we first light our lamps, a film of moisture gathers on the inside of the chimney. This is caused by the moisture from the flame being condensed on the cold glass, for a pint of oil, when burned, will produce a full pint of water were it to be condensed. If we urge the flame of our lamps to the highest point when we first light them, the water will be condensed upon the chimney rapidly, and it will be expanded unevenly, and may be broken. To avoid this, the flame should be small at first, and be gradually increased to the proper size as the chimney is heated.

Benzole, turpentine, tar, etc., contain an excess of carbon, and not enough hydrogen to heat them to the igniting-point, so that, when burnt, they produce clouds of smoke and soot, and therefore cannot be used in our lamps to produce light. Alcohol contains an excess of hydrogen and little carbon; hence it gives off great heat and little light, so that it is not adapted for use in our ordinary lamps for light, but is the best fuel for a lamp to be used with the blow-pipe used by jewelers, mineralogists, etc. In this case a current of air from the lungs is thrown across the flame just above the wick, and the heat of it is thrown against the object to be heated or melted, and the heat of the flame is also increased by the excess of the oxygen supplied to it from the lungs. In the center of this flame is a blue cone-shaped flame, which ends about the middle of the flame. Outside of this is a whiter and more luminous flame, which terminates a little nearer the point of the flame, and beyond this a pale yellow flame, terminating the point of the flame; the blue flame, in the center, is caused by the excess of oxygen from the blow-pipe burning the carbon and hydrogen together. The luminous flame contains carbon in excess, which being burnt, gives out light; this is the hottest flame, and is,

therefore, called the reducing flame. The yellow, or outside flame, contains an excess of oxygen, and is, therefore, called the oxidizing flame. The oil lamp, or tallow candle, is also used with the blow-pipe, but the heat from them is not so intense, because they contain an excess of carbon. Blowing on a candle, or lamp, extinguishes it, because it lowers the heat of the flame below the igniting point of the gases, and in using the blow-pipe, it does not extinguish the flame, because we do not blow on the flame, but into it, for the nosel of the pipe is put into the flame just above the wick, where the heat of the flame is the most intense.

Fires are put out by water partly because it lowers the heat of the flame, below the igniting point of the gases, and partly because the water envelops the wood and shuts off the air. If a person's clothing takes fire, the best way to extinguish it, is to wrap the person in a blanket, carpet, coat, or any thing that will shut out the oxygen and smother the fire. When a house takes fire, it can often be smothered, or made to extinguish itself, by closing up all the windows and doors, so as to shut off the supply of oxygen.

SPONTANEOUS COMBUSTION.

When considerable masses of iron are allowed to rust in a heap, a distinct elevation of temperature is often perceived. And if a heap of iron turnings are moistened with water, and mixed with a little cotton, or some greasy rags, and exposed to the air for a short time, the mass will take fire, spontaneously, and burn the cotton, or rags. Fresh-burnt charcoal will sometimes absorb oxygen so rapidly as to become ignited. Heaps of fine coal and dirt, from coal mines, will often take fire from the heat of the sun; this is caused by the decomposition of the iron pyrites, contained in the coal,

by the moisture and action of the air. Waste cotton, which has been used for wiping machinery, and is saturated with oil, will burst into a flame, if thrown in a heap, near a stove, or in any warm place; this is because it absorbs oxygen rapidly from the air.

B R O N Z I N G .

All bronze castings, such as statues, medals, etc., are liable to become tarnished, and lose their bright appearance; to avoid this, and to renew them after they have become tarnished, it is usual to give them a coating of bronze. The bronzing of copper, or brass castings, may be done by several very simple methods.

A very dark colored bronze may be made by using a little sulphuret of ammonia. The metal to be bronzed is first washed perfectly clean of all greasy substances, and then washed over with the solution, which should be diluted with a little water; and the metal is then dried in a gentle heat; and when dry, it is polished with a hard brush; it should not be rubbed too hard, or with too hard a brush, or the polish may be injured by it.

A black bronze may also be imparted, by heating the castings in a closed box, or room, with sulphureted hydrogen gas. But this bronze is not so good as that produced by the sulphuret of ammonia, and the gas is highly injurious if inhaled.

The green bronzes require a little more time than the black bronze, for they depend upon the formation of the green salt of copper upon the surface of the metal. A dilute solution of sal-ammonia, allowed to dry upon copper, will produce a green tint in a short time, but it is not very permanent. Castings steeped in a strong solution of common salt for several days, comes out coated with a beautiful bronze, which, if washed in

clear water and allowed to dry slowly, will last for a long time. A very beautiful green bronze, having the appearance of ancient bronze, may be produced by taking a small portion of bleaching powder and placing it in the bottom of a dry vessel, and suspending the metal over it. The metal should be slightly heated before it is put into the vessel, and the vessel should be covered, and only enough air admitted to support the combustion of the powder. In a short time the metal will take on a green coating, the depth of which may be regulated by the quantity of the bleaching powder consumed or the time the metal is suspended in its fumes.

The common bronze with a brownish tint may be produced by moistening the metal with a solution of nitric acid and water (after it has been well cleaned of all greasy matter), and then allowing it to dry. After it has been dried slowly it is subjected to gradual and equable heat, which turns the metal to a light brown, becoming darker the more heat is applied.

Another very simple method of bronzing is to wash the metal to be bronzed, in a little alkali, to clean it from all wax or grease, and brush a little dry black lead over the metal and then heating it slowly, but not very hot. This process may be repeated until the desired tint is obtained; and the black lead may either be applied in the dry state, or it may be mixed into a thin paste with water and applied the same as stove polish.

Another bronze solution consists of two parts of copper acetate and one part of sal-ammonia, dissolved in vinegar and filtered. This solution is diluted with water, and brushed or rubbed on the metal and allowed to dry, and the process repeated until the desired hue is obtained. The color of ancient bronze may be obtained by painting the bronze cast with a solution of three parts cream of tartar, one part of sal-ammonia, and six parts of common salt, and the mixture dissolved in hot water. This solution will give to bronze a red-

dish color, and by adding to it eight parts of a solution of nitrate of copper, it will give a more dark-brown color.

There are several other solutions for bronzing, but these are the principal ones that are used. In fact almost any of the acids, if diluted with water and sulphur, form a bronze solution for copper and brass castings; and many of the metallic solutions, such as the weak acid solutions of platinum, gold, antimony, etc., will impart a dark color to the surface of brass and copper castings, if dipped in them. In all the bronzing processes with these solutions, the surface of the copper is converted into a sulphuret, and the success of the process depends a great deal upon the amount of copper the casting contains; yet almost any of the ordinary brass can be bronzed by making the solution stronger and allowing more time in the process of bronzing.

Bronze color is imparted to other castings besides those of brass and bronze, but is not done by corroding the surface of the metal as in bronzing castings that contain copper, but by painting, or by using a solution that holds copper in solution, and deposits it on the metal when dipped in it, as in the case where cast-iron is dipped in a solution of sulphate of copper, or muriate of copper, a thin film of copper is deposited upon the iron. After the castings have been dipped in the solution and sufficiently covered with copper, they are washed in clean water and dried by rubbing in sawdust, and if it is desirable to have a very fine finish, they are next varnished with a little common varnish.

Cast-iron or other metals may be painted in imitation of bronze of all colors, by first coating them with varnish, and when that is nearly dry, dusting them with a metallic powder. When it is desirable to have the work clouded, the powder is put on with a dusting-bag, and when it is desirable to have the work striped in

imitation of marble or other stone, it is done with a paint brush or with the finger. The metallic powder generally used for bronzing is mosaic gold, which can be procured of almost any shade or color; and statues and ornaments of great beauty are made with it. Common dry paint of any desired shade is also used for dusting the work, but it is not so enduring as the mosaic gold.

ZIN C I N G .

Zincing or coating other metals with zinc, is done in different ways. If the metal to be coated is copper or bronze, they are generally coated by exposure to the fumes of zinc, but for iron, the zinc is used in solution. This solution or bath is made by dissolving metallic zinc in muriatic acid, and always having so much zinc in the acid that some of it will remain undissolved. The iron to be coated is dipped in this bath and allowed to remain for a short time, and when it is taken out of the bath, it is perfectly coated with zinc. Another solution is made by dissolving zinc in sulphuric acid; this solution, by evaporation, yields crystals of sulphate of zinc. The solution for depositing is made by dissolving two pounds of this sulphate in one gallon of water; this sulphate is sold in the market all ready for use, and when only used in small quantities, it is more economical to buy it than to make it. This solution cannot be used for depositing the zinc without the aid of a battery, but the zinc is very easily deposited from it with the aid of a small battery, and may be deposited upon black-leaded surfaces, in the same manner as copper, but articles formed by depositing zinc upon black lead are very brittle, from the crystalline character of the zinc, unless a powerful battery is employed, and the article on which the deposit is made is

kept in constant motion, so as to give the zinc a more fibrous structure. Zinc is principally applied as a coating upon iron to protect it from rusting, and is much used for coating sheet-iron, water pipes and small castings that are exposed to water, such as those used for washing machines, clothes wringers, etc. Iron, when coated with zinc, is called galvanized iron.

BLACKING IRON CASTINGS.

For common work, the blacking generally used is common coal tar; and for the finer work, Japan varnish is used; and for work that is exposed to the heat of a fire, black lead, moistened with a little water or benzole, is used, as in the common stove blacking. But stoves that are exposed to the weather, or sample-stoves in warehouses, should be blacked with black varnish, and the varnish dusted with dry black lead, and rubbed dry with the hard brush; this gives a beautiful polish, and one that will not rust easily; and if it does get slightly rusted it can easily be rubbed off with the brush, and the polish will look as fresh as new. Fine ornamental castings are heated to the blue annealing heat, and then coated with black copal varnish, and dried at the same degree of heat. The heat takes off the gloss of the varnish, but it may easily be returned by giving the work another very light coat and heating it gently. For enameling mantel and grate fronts, an enamel varnish is used that does not lose its gloss when heated to the highest heat of the enameling oven, and gives a very fine finish of any desired color. A paint that imparts a rich lead color to iron is made by heating the oxide of lead in an iron pot, and stirring into it when hot some flour of sulphur, and mixing with oil; this paint may be applied when cold, and gives a fine lead color, which is very lasting.

The permanent coating of one metal by another is generally done by the electric process, or water-gilding process; but these processes of coating metal form a separate branch of business from the foundry business, and are but little practiced by foundrymen. Several books have been published upon electro-plating and water-gilding, and they can be obtained from any of the publishing houses that publish scientific books, by any one that may want a knowledge of that branch of business.

RECIPES FOR WORKING STEEL.

FOR TEMPERING.

Six quarts of soft water, two ounces of pulverized corrosive sublimate, and two handfuls of common salt make a good solution for tempering.

ANOTHER.

Two ounces saltpetre, two ounces sal-ammonia, two ounces alum, and one pound and a half of common salt, and the whole dissolved in three gallons of soft water, make a good tempering solution.

Steel that is very high, and cannot be tempered in water solutions, may be tempered by heating it to a cherry red, and sticking it in the ground or sand to cool.

FOR WELDING.

Two ounces copperas, one ounce saltpetre, six ounces common salt, one ounce of black oxide of manganese, one ounce prussiate of potash; the whole to be pulverized and mixed with three pounds of welding sand.

TO ANNEAL STEEL.

Steel may be annealed and made so soft that it can almost be shaved with a knife by heating it to a cherry

red, and laying it between two pieces of yellow poplar wood, and bolting the wood together so as to exclude all the air from it. It should be left in the wood until perfectly cold.

TEMPERING DRILLS, ETC.

To prevent steel taps, drills, etc., from springing when tempered, the steel should be forged to the desired shape and then heated to a cherry-red and annealed in charcoal or ashes before the tool is turned or finished. After it has been annealed it should not be straightened by hammering, for the springing of the steel, when it is being tempered, is all caused by its being hammered in one spot more than another, which causes the crystals to be more compact in spots, and when the steel is heated they equalize, which warps the steel.

DRILLING HARD IRON.

Hard iron or steel may be drilled by using turpentine and camphor-gum for keeping the drill cool.

C E M E N T .

In stopping holes in castings, or for covering scars, a cement may be made of equal parts of gum-arabic, plaster-of-Paris and iron filings, and if a little finely pulverized white glass be added to the mixture, it will make it still harder. This mixture forms a very hard cement that will resist the action of fire and water. It should be kept in its dry state and mixed with a little water when wanted for use.

A cement for making joints in water and steam-pipe, or in any work where two pieces of metal are joined together, and it is desirable to make a perfectly tight joint, may be used, made of iron filings or turnings mixed with sal-ammonia. The proportion of sal-ammo-

nia is very small; only about a half pound is used to fifty pounds of filings. This cement is mixed when wanted for use, and is driven into the joint with a cold chisel or other tool.

The best kind of black-lead crucibles can be obtained from the Jersey City Crucible Manufacturing Company, at Jersey City, N. J.

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